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THE GEOLOGY, PETROLOGY AND PHYSIOGRAPHY OF THE OMEO DISTRICT, NORTH-EASTERN VICTORIA

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[Read 10 March 1949]

Abstract

A reconnaissance survey of an area in the Omeo-Glen Wills-Benambra district has been carried out.

Physiographically, this area forms part of a group of uplifted and tilted fault blocks of probably late Pliocene or Pleistocene age, on which remnants of a pre-Miocene peneplain are preserved.

The bed-rock of the area consists of schists and gneisses, forming part of the metamorphic belt of north-eastern Victoria. The former are, at least in part, the metamorphosed equivalents of the Upper Ordovician sediments outcropping on the flanks of the belt, while the latter are closely related to massive granites and granodiorites of Lower Devonian (?) age. A gradual increase in the metamorphic grade of the schists as the major gneissic intrusions are approached is traced by the incoming of biotite, cordierite, poikiloblastic muscovite, sillimanite, etc., and the gneisses are classified according to the relative importance of contamination, recrystallization and mechanical deformation in their formation. The tourmaline-rich muscovite granite of Mt. Wills and numerous aplites, pegmatites, etc., may represent the last phases of this period of igneous activity.

Younger sediments of probably Middle Devonian age are represented by shales, sandstones and conglomerates of Mt. Tambo, which overlie the schists and gneisses with a marked angular unconformity, and by the shales, sandstones, conglomerates and limestones of the Wombat Creek and Limestone Creek formations.

The red granite in the vicinity of the Blue Duck Hotel, and the syenites and granite porphyries of the eastern portion of the area are referred to a second period of igneous activity, probably of late Upper Devonian age, since they intrude certain of the Middle Devonian sediments. They are associated with abundant hypabyssal and extrusive rocks of composition comparable to the plutonic types and including some highly alkaline types. A group of more basic rocks, including diorites, lamprophyres, dolerites, etc., which are restricted in amount but very widespread in occurrence, are also tentatively correlated with this period of igneous activity, since many of them are characterized by the presence of significant amounts of albite.

The only post-Palaeozoic rocks in the area are the flows of Older Basalt in the Bogong High Plains and in the Mt. Hotham-Dargo High Plains area, and the more restricted occurrence of Newer Basalt at Frazer's Tableland, north of Benambra township, the two groups being readily distinguished by petrological and physiographic characteristics. Richly fossiliferous leaf beds and a thin seam of brown coal are associated with the former at a locality south of Mt. Jim. Nepheline phonolites near Omeo are also tentatively correlated with one of these Tertiary periods of igneous activity.

Finally, an attempt at listing and classifying the known mineral resources of the area is made.

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Introduction

The area to be discussed in this paper is a roughly triangular block of country in the upper portion of the Mitta Mitta catchment, extending from near Omeo in the south to Mt. Bogong in the north-west and Leinster Station in the north-east. Of the total area of approximately 600 square miles, the east and south-central portions have been studied in greatest detail, but the scale of the structural and petrological units in this part of the State is such that their essential relationships are only revealed by the consideration of relatively large areas. Also in considering the physiography it is necessary to include the headwater regions of the Tambo and Wentworth Rivers in the south, Limestone Creek in the east, and the Kiewa River in the north-west.

For field mapping Parish Plans, where available, were used as base maps, supplemented by aerial photographs of the country about Omeo supplied by the Forestry Commission, and a detailed drainage map of the Bogong High Plains compiled by the State Electricity Commission. The author is also indebted to the Royal Australian Air Force for permission to accompany one of its bushfire patrols on a routine flight over the area. Pace and compass surveys were relied upon for mapping geological and topographical details, heights being calculated from aneroid readings.

Previous Work

Of the very large number of previous references to this area, only the most important can be listed at this stage, and a number of others will be discussed in the relevant sections of the text. Of the remainder, which are listed in the bibliography, but to which no individual references have been made, the majority are notes concerned essentially with the economic and engineering details of one or other of the numerous mines formerly active in this area, and a few are merely recapitulations of earlier work.

The foremost contributions to our knowledge of the district, both in point of time and of importance, are the papers of A. W. Howitt (1876, etc.) who was the first to publish detailed descriptions of the plutonic and metamorphic rocks of the area, recognizing transitions from the mica schists of the metamorphic belt to the unaltered Ordovician sediments on either flank, and setting up criteria for the distinction between metamorphic rocks of igneous and sedimentary origin.

At about the same time, J. Stirling (1882, etc.) recognized the Bogong High Plains as the dissected remnants of an uplifted peneplain, an interpretation which has been fully upheld by later studies. Other workers who added to the knowledge of the area towards the turn of the century include W. H. Ferguson, O. A. L. Whitelaw, R. A. F. Murray, E. Lidgey, H. S. Whitelaw and E. J. Dunn, whose various papers will be referred to again later.

In more recent years, a series of more specialized studies has also been carried out in the area. These include detailed petrological accounts of the nepheline phonolites of Omeo (Skeats 1912), of certain metamorphic and igneous rocks (Tattam 1929), and of the syenites of Mt. Leinster (Broadhurst and Campbell 1932). Similarly, a number of the major physiographic features of the district have been re-examined in recent years, the studies of Kenny (1937d) and Thomas (1937), on Lake Omeo, and of Hills (1938) on Frazer's Tableland being of special interest.

In addition to papers dealing with the area itself, a number of studies in adjacent or similar areas will also be referred to for purposes of comparison and possible correlation. The most important of these are N.E. Benambra (Edwards and Easton 1937), Bindi (Gaskin 1942), and portions of the metamorphic complexes in N.S.W. (Joplin 1942, etc.), the first of these, based on the detailed mapping of a large area by J. G. Easton, being especially instructive.

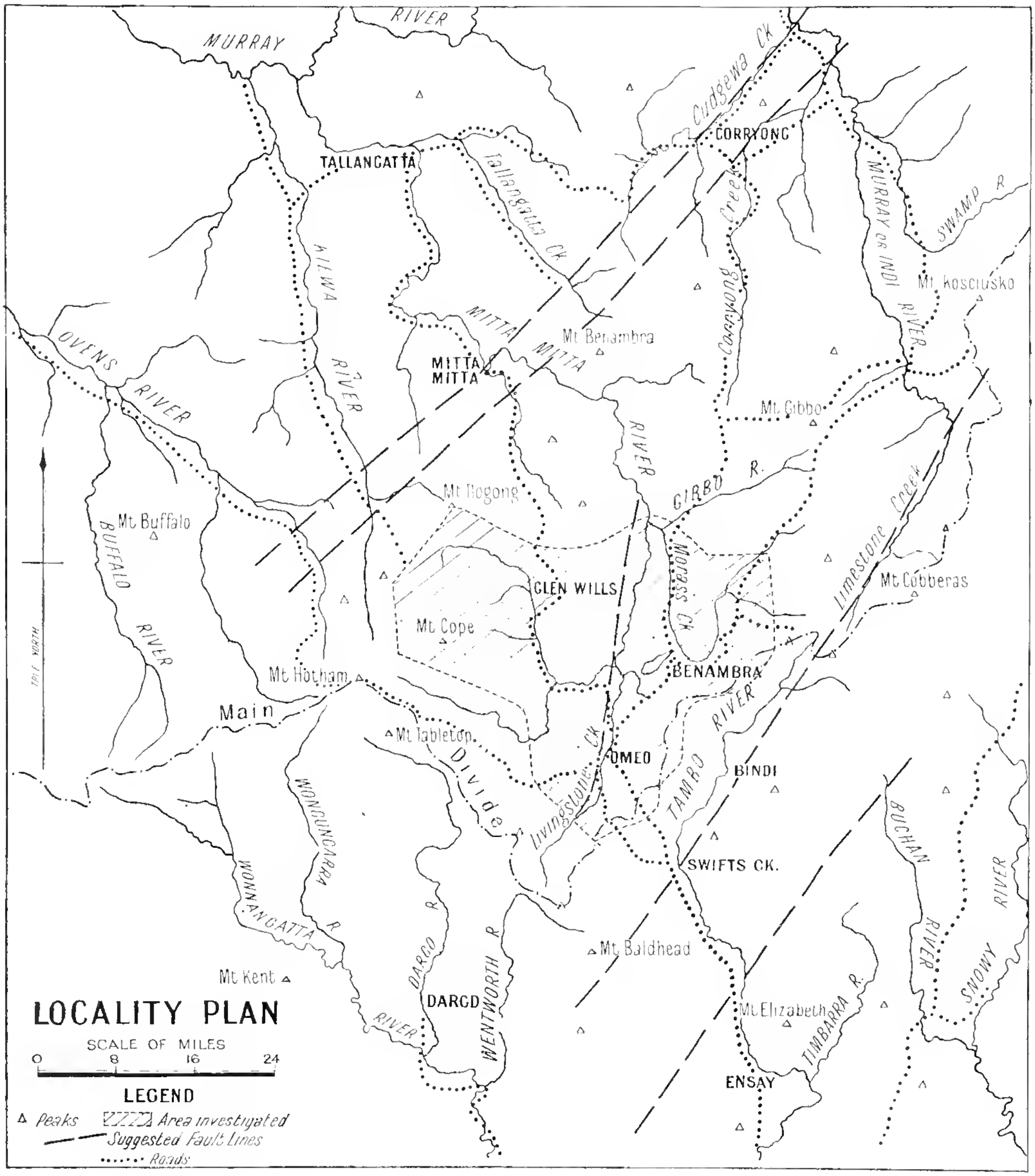


FIG. 1.—Locality Plan.

Physiography

Drainage Systems

Most of the area falls within the drainage basin of the Mitta Mitta or Big River. This river rises in relatively gentle gullies west of Mt. Nelse at about 5500 feet, first flowing northwards. Its valley then becomes deeper and steeper and it turns to the south-east and flows in a valley with a depth of from 2000 to 3000 feet which separates Mt. Bogong and Mt. Wills from the Bogong High Plains proper. Near the confluence with Glen Wills Creek the valley cross-section becomes more open and river gravels occur 50 feet above the level of the stream. From about two miles south of this confluence the valley is again gorge-like. Valley-in-valley structure is obvious, remnants of the old valley being found at progressively higher levels downstream to Hinnomunjie Bridge. Here the river abruptly emerges on to an alluvial flat about half a mile wide and two miles long, at an altitude of about 1800 feet.

The chief tributaries in this region, Middle Creek and the Bundarra, Cobungra and Victoria Rivers, which rise in the High Plains and flow generally westward, show similar features: that is, a gentle headwater region, passing rapidly into a deeper and steeper portion which ultimately opens into small alluvial flats, as at Shannon Vale and Cobungra Station. Rejuvenation, with its resultant valley-in-valley structure, has progressed up these valleys for distances depending upon the size of the particular stream and the amount of rejuvenation undergone by the Big River at its confluence with the stream.

In the country about Hinnomunjie Bridge the Big River swings in a large bend from a general southerly to a general northerly course, the centre of this bend being the Knocker, a mountain about five miles east of Glen Wills. Similar changes of direction occur in two of its lower tributaries, the Gibbo River and Morass Creek, and to a lesser extent in the Cobungra and Bundarra Rivers. North of Hinnomunjie Bridge the valley gradually deepens and becomes gorge-like, valley-in-valley structure again being prominent. The difference in level of the old and present valleys is from 800 to 1000 feet in the vicinity of the confluences of Wombat Creek and the Gibbo River, and to the north may be even greater. All traces of the old valley are, however, lost some distance before the river reaches Mitta Mitta township, where it emerges on to another set of alluvial flats at an altitude of about 800 feet. These flats persist for the remainder of its course.

Livingstone Creek rises near Mt. Delusion at the tip of the great southerly bend which the Main Divide describes in this region. To the north of the junction of New Rush Creek, some twelve miles south of Omeo, its course is characterized by alternating river flats and small gorges up to 200 feet in depth, good examples of such gorges occurring near the Reedy Creek confluence and just downstream from Wilson's Creek. The river flats are frequently associated with deposits of old coarse gravels at levels of up to 150 feet above the present creek bed, as at Hinnomunjie Swamp, five miles north of Omeo, and at Dry Gully. A striking feature of the valley of Livingstone Creek is its pronounced asymmetry, shown by steeper and higher slopes on the west than on the east and by the more pronounced valley-in-valley structures in the western tributaries such as Dry Gully and Jim and Jack Creek, as compared with eastern tributaries such as Wilson's Creek and Day's Creek. This asymmetry can be traced some distance down the valley of the Mitta Mitta River beyond Hinnomunjie Bridge, but north of Eight

Mile Creek the effect is masked by the general deepening of the valley already referred to.

Morass Creek enters the area from the east, flowing around the north and west slopes of McFarlane's Lookout and describing a wide arc around the southern slopes of Mt. Brothers before joining the Mitta Mitta River by way of the Gibbo River. Locally it has caused alluvial flats north of McFarlane's Lookout and north-east of Mt. Leinster, ascribed by Broadhurst and Campbell (1932) to the effect of hard bars of syenite. Close to Benambra, at an altitude of about 2400 feet, the stream meanders over very much larger alluvial flats up to two miles wide, which Hills (1938) has shown to be caused by the damming of the stream by the Newer Basalt of Uplands, about six miles north of Benambra. Beyond that point the stream has been rejuvenated similarly to the Mitta Mitta and has cut a gorge comparable in depth with that of the latter.

North-east of Mt. Brothers a low saddle, only about 400 feet above the present valley of the stream, separates it from the headwaters of Deep Creek, the valley of which may have been the former course of Morass Creek. If so, the diversion around the southern end of Mt. Brothers is comparatively recent, but the reason for it has not been discovered.

Wombat Creek shows nothing of special interest in its upper course, flowing in a uniformly steep but gradually deepening valley down to a point almost opposite Limestone Gap, sometimes referred to as Toak's Gap. From there it turns abruptly south-east to join the Mitta Mitta at almost the same point as the Gibbo River. From a study of the Newer Basalt outliers preserved on the upper slopes of the present river valleys, Kenny (1937a) deduced that the drainage in this part of the valley has been reversed. Before rejuvenation the old course of the Mitta Mitta followed the lower part of the present Wombat Creek valley, crossed Limestone Gap and rejoined its present valley about eight miles north of the present Wombat Creek confluence. The reason for the diversion is not known, but the change would appear to date from the time of rejuvenation, i.e., probably Pleistocene or late Pliocene.

The north-western portion of the area is drained by the East Kiewa River, whose main headwaters are the two streams known as the Rocky Valley branch and the Pretty Valley branch which join at Bogong township. They have similar relatively simple valley forms, rising on the Bogong High Plains as very gentle gullies which open out on to restricted alluvial flats at Rocky Valley and Pretty Valley proper, at about an altitude of 5300 feet. These flats are drained by very steep gorge-like valleys which in six or seven miles drop to about 2100 feet at Bogong township. From here the valley of the East Kiewa River is somewhat more open. Near Tawonga, at about 1100 feet, alluvial flats appear and persist for the remainder of the course, as in the valley of the Mitta Mitta.

The Tambo and Wentworth Rivers drain the southern slopes of the Main Divide in the south-central and south-east parts of the area. On the whole they show less anomalous features than the north-flowing streams. Minor examples of probable river capture are provided by the headwaters of the Wentworth at Jirnkee Gap, and by Scrubby Creek, a tributary of the Tambo south-east of Mt. Sisters. In each case the streams show a sudden change in direction from north to south and low saddles across the Main Divide suggest their former courses. In the first example the saddle is still at a distinctly lower elevation than the headwaters of the stream so that a water race to Swift's Creek tapping the Wentworth River five miles below its source was brought over the Divide at the saddle.

A feature of the Tambo River, regarded as significant by Griffith Taylor (1911), is the distinct asymmetry of its drainage basin, through its receiving no major tributaries from the west.

The Main Divide has marked asymmetry, the headwaters of the south-flowing streams invariably being steeper than those of the north-flowing ones. This is clearly visible at Tongio Gap and Cassilis Gap but is a general condition as far east as Marengo and as far west as Mt. Phipps. It has been attributed to differences in the mean annual rainfall by Stirling (1882) and later workers, but other causes will be invoked in a later section of this work.

Mountain Peaks and Ranges

Many previous workers have pointed out that the highest mountains of the area are not situated on the Main Divide but at distances up to twenty miles to the north. The Divide itself here forms a large southerly bend extending approximately from Mt. Leinster in the east to Mt. Hotham in the west. It contains a number of low saddles such as Tongio Gap, 2450 ft., and Cassilis Gap, 2500 ft., through which pass roads leading south from Omeo.

In the western half of the area a nucleus of high country is provided by the Bogong High Plains of average elevation 5300 ft. from which rise several peaks attaining heights a little over 6000 ft. These include Mt. Hotham, Mt. Cope, Mt. Fainter, Mt. McKay, Mt. Nelse and Mt. Jim, of which only Mt. Hotham is situated on the Divide. To the north of this group, and separated from it by the deep valley of the Big River, lies the unbroken range connecting Mt. Bogong (6500 ft.) with Mt. Wills (5750 ft.). Further north again, however, in the area drained by Snowy and Little Snowy Creeks, no peaks exceed 4200 ft.

In the central part of the area a progressive decrease in the level of the major peaks is apparent, eastward from the Bogong High Plains, a minimum being reached at about a north-south line through Omeo. The highest points are Mt. Livingstone (4000 ft.), Mt. Delusion (4500 ft.), Mt. Baldhead (4600 ft.) and the Knocker (4950 ft.). It is in this region that the most pronounced saddles of the Main Divide occur.

East of the north-south line through Omeo the elevation of the major peaks increases but the nature of the relief undergoes a gradual change. Isolated peaks rather than ranges and plateaus are the rule, and differential erosion has played a much more important role in determining the present topography. The main peaks are Mt. Brothers (4650 ft.), composed of syenite, Mt. Sisters (4200 ft.), composed of granite porphyry, Mt. Tambo (4850 ft.), of conglomerate, and Mt. Leinster (4750 ft.), of syenite. The last three are situated on the Main Divide. The continuation of the Mt. Bogong-Mt. Wills ridge is also strongly represented on this side of the Mitta Mitta valley and includes a group of rugged peaks and ridges culminating in Mt. Gibbo (5700 ft.).

Relations to Adjacent Areas

Considering the area as a whole and in relation to adjacent areas, the most striking features are the close accordance of the summit levels of the various groups of peaks within it and its sharp demarcation from adjoining physiographic units. The summit levels show a gradual decrease to the south of the order of 2000 feet in fifty miles, or about 1 in 120. This is brought out by a high-point profile drawn through the area in a N.N.W.-S.S.E. direction, in which all the main peaks

are shown as projected on a single section line. The sharp discontinuity just north of Mt. Bogong and the similar, but rather smaller, drop south of Mt. Baldhead are clearly revealed. The discordance of points corresponding to Mt. Buffalo and to the Cobberas is very obvious and indicates that the physiographic unit under consideration does not extend beyond the Ovens valley to the west nor Marengo to the east. The general accordance of the points representing the base of the Older Basalt flows, in a line parallel to and from 400 to 800 feet below that of the summit levels also indicates that this alignment is not accidental, and suggests that the area had already been dissected to a moderate depth in pre-Older Basaltic times.

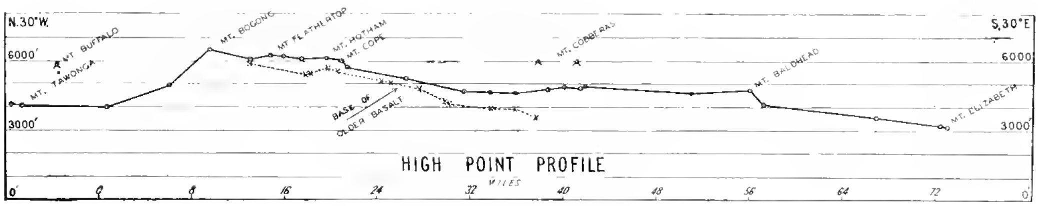


Fig. 2.—High Point Profile.

Previous Interpretations

The most important previous interpretation of the physiography is that of Griffith Taylor (1911) in which a series of major river captures was postulated to account for the present-day topography and drainage. The Big River, Gibbo River, Morass Creek, Cobungra and Victoria Rivers were thought by him to have flowed originally southwards into the Tambo River by way of what are now the low saddles in the present Main Divide, and to have been captured by the headwaters of a north-flowing stream which headed back through the then existing divide, of which the Mt. Bogong-Mt. Wills and Mt. Gibbo-Mt. Pinnibar ranges are the present-day remnants. This theory is supported by the existence of the low saddles, by the present asymmetry of the Tambo drainage system, and by the pronounced elbows and boat-hook bends in the courses of the various streams concerned, giving rise to so-called "crossed forks" at the supposed points of capture.

The present work tends to confirm that such major river captures have taken place but, since steepening of the valleys below the points of capture is no longer in evidence, these changes must be referred to an earlier cycle of erosion. There is, however, strong evidence suggesting that the high Mt. Bogong-Mt. Gibbo group of mountains owe their elevation to comparatively recent earth movements, so that the present river system is antecedent to them. The formation of the Mitta Mitta gorge can thereby be accounted for without assuming the breaching of an old divide.

Fault Lines

The existence of two physiographically unlike regions divided by a line trending N.E.-S.W. through Tawonga was indicated by Tattam (1929). North of the line the major rivers, the Kiewa and Mitta Mitta, flow in wide open valleys over alluvial flats up to four miles in width, separated by ranges rising abruptly from the flats but seldom exceeding a height of 4000 ft. To the south the valleys are steeper, often gorge-like, and the main peaks may exceed 6000 ft. Easton (1937) suggested

that this marked discontinuity could be accounted for by a major fault running through Simon's Gap near Tawonga, up the valley of Mountain Creek, crossing the Mitta Mitta near Granite Flat and continuing down the valley of Cudgewa Creek to the New South Wales border. This has been termed the Tawonga or Mountain Creek fault.

Considering the high-point profile from this point of view, it appears that the area between Mt. Bogong and Mt. Baldhead represents a block or group of blocks uplifted approximately 2500 ft. relative to the adjoining northern area, and tilted to the south at a low angle. However, the possibility of this throw being distributed over two or more parallel or sub-parallel zones of movement cannot be neglected, and is suggested by the alignment of creeks and saddles in N.E. Benambra along two main lines, represented by Cudgewa Creek and the lower portion of Corryong Creek respectively.

The south-eastern boundary of the tilt block is indicated on the high-point profile by a break just south of Mt. Baldhead, although the displacement of the summit levels is only of the order of 500 ft. However, a line drawn through this point, parallel to the strike of the Mountain Creek Fault, again coincides with a remarkable alignment of streams and low saddles, such as would be expected along the line of weakness marking the position of a major fault. The upper portion of the Tambo River, the valley of Limestone Creek and the north-easterly-flowing portion of the Indi River, north-east of the Pilot, all follow this line.

A strong scarp, 400 ft. to 500 ft. high, running approximately N.N.E.-S.S.W. and facing south-east, can also be recognized in the Tambo valley between Ensay and Swift's Creek and may form part of this or a related fault line.

The most striking effect of these faults on the drainage system has been the rejuvenation of the streams draining the upthrown blocks. The Ovens, Kiewa, Mitta Mitta and Indi Rivers all flow in deep gorge-like valleys for part of their course, emerging more or less abruptly on to gentler valleys and alluvial flats on the downthrown blocks. In the case of the Ovens and Diamantina or West Kiewa River, rejuvenation is complete up to the headwater region, but the Mitta Mitta and East Kiewa Rivers still show well-defined knick-points.

The former, carrying the larger volume of water, and hence possessing superior powers of erosion, has cut back its gorge to the vicinity of Eight Mile Creek, a distance of approximately 25 miles from the line of the Mountain Creek Fault, with a corresponding development of knick-points in its major tributaries, such as Morass Creek, Wombat Creek and the Gibbo River. In the East Kiewa River, on the other hand, rejuvenation has only proceeded for a distance of ten or twelve miles and the knick-points are represented by the outlets of the very gentle locally swampy basins of Rocky Valley and Pretty Valley, in which extensive alluvial flats have been deposited by the creeks.

These alluvia have been attributed by Kenny (1937c) to the blocking of the old outlets of these basins by the basalts of Mt. Jim and Basalt Hill respectively. However, in view of the great age of these flows and their probable much greater original extent, it is unlikely that any portion of the pre-Older Basalt drainage system now survives as such, and it is most improbable that such a relatively minor modification should have been preserved from Oligocene or Lower Miocene times.

An alternative explanation in terms of the tilt of the upthrown block appears more probable. This tilt has resulted in a reduction of the grade of the north-flowing streams throughout the affected area, which should thus tend to develop alluvial flats, while the grade of the south-flowing streams has been increased and their

powers of erosion augmented. This difference would account not only for the presence of alluvial flats in Rocky Valley and Pretty Valley and their absence at corresponding points in the headwater regions of Middle Creek and the Bundarra and Cobungra Rivers, but also for analogous features elsewhere in the area. Thus it explains the previously mentioned asymmetry of the Main Divide with very much steeper southern than northern slopes, and may also account for a number of river captures in which originally north-flowing streams have been diverted to the south. The Big River near Mt. Arthur, the Wentworth at the Jirnkee Gap and possibly also Scrubby Creek south-east of Mt. Sisters are examples of this type of capture.

The Livingstone Creek Fault has left a major physiographic feature which can be traced for almost twenty miles along the steep west banks of the Livingstone Creek and Mitta Mitta valleys, between Jim and Jack Creek in the south and Eight Mile Creek in the north. The vertical displacement on this fault is of the order of 600 ft. to 800 ft., and from the excellent state of preservation of the scarp its age is regarded as being no greater than that of the youngest major Central Victorian and South Gippsland faults, possibly post-Pliocene.

This fault has again given rise to marked rejuvenation and valley-in-valley formation of the streams draining the upthrown (western) block, especially the Big River and its major tributaries. The western tributaries of Livingstone Creek have also been affected, Dry Creek, Mountain Creek and Jim and Jack Creek providing the best examples.

The effect on the Mitta Mitta River below Hinnomunjie Bridge and on Livingstone Creek itself, both of which might be described as fault-angle streams, has been more complex. Wherever the original course of the streams traversed portions of the present upthrown block, they have been diverted to the east, leaving old river gravels perched between 600 ft. and 800 ft. above their present valleys, as on the old Glen Wills-Benambra road over the Knocker and at Mt. Mesley, west of Omeo township. Upstream of such points, the streams were temporarily dammed back, and heavy, rudely stratified gravels, with interbedded sands and clays, were deposited, probably under lacustrine conditions. These attain a thickness of up to 100 ft., as at the mouth of Dry Creek and on the Omeo-Hinnomunjie Bridge road, west of Hinnomunjie Swamp, where they have been tested by bores (Stirling 1887c). In every case, the creek has completed the downcutting of its valley to the base of these gravels, so that its present level is everywhere below that of its pre-fault ancestor, the difference increasing northwards and possibly reaching 200 ft. near the mouth of Reedy Creek, about eight miles north of Omeo.

The Reedy Creek-Morass Creek Line is another probable line of weakness. East of Omeo township the spurs rise, at first gently but finally much more steeply, to the Main Divide, which gradually decreases in altitude from Mt. Sisters to the Tongio Gap. In the northern part of this area the headwaters of Reedy Creek flow practically parallel to the Divide, which rises abruptly. North of the Benambra lowlands the line of this abrupt rise is taken up again by the steep west face of the Mt. Brothers massif, along the foot of which Morass Creek flows. This line coincides closely with the western boundary of that physiographic region in which differential erosion has exercised a controlling influence upon topography, suggesting that uplift in this portion was initiated rather earlier than elsewhere in the area. The Reedy Creek-Morass Creek Line may thus represent an older line of weakness than those discussed above. The evidence for this line being a fault is, however, not conclusive.

The important role ascribed to faulting in this area is in good accord with observations in the Kosciusko district, about 45 miles to the north-east, where Browne, Dulhunty and Maze (1944) have described a series of tilt blocks with comparable displacements and have identified valley-in-valley structures, fault-angle streams, etc.

Evolution of Present Land Surface

A number of stages in the evolution of the present-day topography can be reconstructed from a study of the various remnants of older erosion surfaces preserved in the area. The oldest land surface of which remnants may still be recognized is represented by the concordant summit levels of the highest peaks, as shown on the high-point profile. This had already been maturely dissected in Older Basaltic times and must therefore be identified with the epi-Cretaceous peneplain postulated by a number of workers in other parts of the State (Hills, 1934, 1940, etc.).

At the time of extrusion of the Older Basalts, this had been maturely dissected to give local relief of the order of 1000 ft., the value increasing generally in a southward direction, as indicated by the maximum difference in level between the remnants of the epi-Cretaceous peneplain and the base of the Older Basalt flows. The widespread occurrence of sub-Older Basaltic gravels, clays and leaf beds suggests the existence of a mature river system at this stage, but the extent to which the Older Basalt flows modified this drainage cannot be ascertained.

The first movements leading to the present elevation of the area cannot be dated accurately, but must pre-date the Newer Basalts by some considerable time. They appear to have consisted of a regional upwarp, possibly accompanied by local faulting, as on the Reedy Creek-Morass Creek line, and the reversal in the direction of flow of the Big River, Gibbo River, and other major streams may date from this time.

By Newer Basaltic times (Late Pliocene-Pleistocene?), the present drainage system had been developed with most of its major features. In the western portion of the area, relief was still very moderate, especially in the vicinity of the Bogong and Dargo High Plains. In the eastern portion, on the other hand, relief of the order of 1500 ft. was typical, and greater differences existed locally, as at Mt. Brothers, Mt. Tambo and Mt. Leinster.

As shown by the configuration of the old valleys of rejuvenated streams, and by the sub-Newer Basaltic leads corresponding to the old Mitta Mitta and Morass Creek valleys, the rivers of this time flowed in wide, gentle valleys, from the edges of which the major peaks and ranges rose relatively steeply. The general appearance of the area would thus have been closely comparable to that still predominating on the adjacent northern block, e.g., at Mitta Mitta and Tawonga townships.

The effect of the Newer Basalt which flooded the Mitta Mitta and Morass Creek valleys from Uplands to the vicinity of Limestone Gap, a distance of approximately ten miles, was purely local. Morass Creek was dammed back temporarily and the deposition of alluvial flats took place for about eight miles upstream of the barrier at Uplands, the maximum width of the deposits being about two miles.

The most recent movements in the area are the previously described faults along Mountain Creek, Livingstone Creek and the upper Tambo River, none of which have caused any major changes in the courses of the larger streams. The age of these faults relative to the Newer Basalt cannot be determined, since the time required for the cutting back of the Mitta Mitta gorge from the line of the Mountain

Creek fault to the lowest point reached by the basalt is not known. The basalt may thus have been extruded after the faulting had occurred, but before the rejuvenation had extended to that portion of the stream which the basalt now covers.

Local Base Levels

The present stream systems appear to be re-establishing equilibrium at levels between 800 ft. and 1200 ft., as seen in the Mitta Mitta River at Mitta Mitta township, in the Kiewa River at Tawonga, etc. Local base levels, due to geological controls, play an important part in the development of some of the major streams. Thus Morass Creek, which has deposited alluvial flats behind hard bars of syenite at Mt. Leinster and McFarlane's Lookout, has been described as a superimposed stream by Broadhurst and Campbell. The Tambo River at Doctor's Flat and at Ensay shows the same features, the metamorphic aureole around the granitic mass of Mt. Hopeful acting as a hard bar in this case.

Glaciation

No traces of Recent or Late Tertiary glaciation were found anywhere in the area, and all the evidence cited by previous authors was found to be readily explained by other means.

Browne, Dulhunty and Maze (1944) have shown that evidence of glaciation in the Kosciusko area is restricted to levels above about 5000 ft. For this reason, references by Lendenfeld (1886) to a terminal moraine in Mountain Creek at 2000 ft., and by Stirling to glacial pavements and former moraine-dammed lakes in the Livingstone Creek valley at about the same altitude, may be disregarded. Moreover, the formation of these lakcs has already been shown to be related to movements on the Livingstone Fault.

The same authors also claim evidence of glaciation on Mt. Bogong at levels above 5500 ft., including striated pavements and glacial erratics, the latter being described as facetted boulders of hornblende diorite, originally derived from the High Plains to the south. During the present investigation, abundant outcrops of these diorites were found throughout the highest portions of the Mt. Bogong massif, and the presence of the so-called facetted boulders is thought to be due to their well-developed tendency to break into angular blocks parallel to closely spaced joint planes. In addition, the northern portion of the Bogong High Plains, immediately opposite Mt. Bogong, was found to be singularly free from these diorite dykes, no outcrops being found nearer than the East Kiewa valley, and then only at elevations of 4500 ft. or less. The striated pavements proved equally inconclusive, no occurrence being seen which could not be satisfactorily explained by the action of water- or wind-borne debris.

Geology

Schists

Most of the area falls within the metamorphic belt of north-eastern Victoria. The sedimentary members of this metamorphic complex, referred to as the Omeo Series by Howitt (1887), are regarded as the altered equivalents of mainly the Upper Ordovician slates and sandstones of the lower part of Wombat Creek and elsewhere, recorded by Ferguson (1899) as containing *Climacograptus bicornis* and *Dicellograptus elegans*. The possibility of at least some of these rocks being the equivalents of Middle Ordovician or even older sediments is, however, indicated

by the occurrence of Middle Ordovician graptolites on the lower Gibbo River, at a locality some miles east of the above locality. (Dr. D. E. Thomas, personal communication.)

Throughout the area arenaceous and argillaceous beds alternate with great regularity, the thickness of the individual beds ranging from a few inches to a few feet. No calcareous beds nor conglomerates were encountered and no trace of any interbedded volcanic or pyroclastic rocks were seen. In the absence of marker beds no estimate of the total thickness of the beds involved can be given.

Structures

The belt as a whole is markedly asymmetric in this area, the zones of medium and low grade schists being very much wider on the eastern flank than on the western. Thus the transition from almost unaltered sediments to strongly foliated, medium-grained two-mica schists in the middle and upper portions of Wombat Creek occupies five to six miles, while corresponding types at Mt. Hotham can be found within one or two miles of each other. Since the dominant dips, at least in the vicinity of Omeo, are to the east, these observations conflict with those of Joplin on the Cooma complex (1943), in which she found the metamorphic zones to be widest on the flank away from the dominant dip of the beds.

In the central part of the area, strikes of from 330° to north-south and dips of 60° to 80° are typical, easterly dips predominating somewhat, as shown by the almost continuous section along the lower part of Reedy Creek. Major fold axes are spaced at distances from five to ten chains apart, but minor folds of amplitudes from a few inches to about half a chain are not uncommon. The crests of the folds are typically sharp but not angular. The pitch is usually small, although a number of minor folds in the lower part of Dry Creek show south-easterly pitching of from 30° to 90°. Where overfolding has occurred the overfolded limb may be inclined as much as 20° from the vertical, but even then the folds are rarely isoclinal. Such structures are revealed in Reedy Creek, the overturning being to the west.

As the centre of the metamorphic belt is approached in the vicinity of the Bogong High Plains, the dips tend to be lower, and the beds are sub-horizontal over considerable areas. Insufficient time was available to map these structures in detail, but work now being carried out by officers of the Geological Survey may ultimately reveal the significance of this difference, which tends to support Tattam's suggestion that the metamorphic belt as a whole represents an anticlinal structure.

Further north again, on the southern slopes of Mt. Bogong itself, the dips are uniformly N.E. at 60° to 70° over an area of several square miles, suggesting isoclinal overfolding. Similar relationships have been described by Tattam from the adjacent Mitta Mitta and Tawonga districts, the dips there, however, being to the S.W. No reason for this reversal can be suggested, but an extension of the present work to the northern slopes of Mt. Bogong and the headwater regions of Snowy Creek would be expected to reveal other significant features.

Regional deviations of the strikes from the dominant N.W.-S.E. direction are found in three main areas. Thus irregular variations, not traceable to any definite cause, are found in the upper portions of the Knocker, east of Glen Wills, and on the eastern slopes of the Livingstone Creek valley in the vicinity of Omeo.

A more widespread deviation is noticeable in the eastern portion of the area, especially in the vicinity of Mt. Brothers and the Marengo Gap, where strikes bearing between 30° and 60° are dominant over areas of several square miles.

The transition is accompanied by the development of pitching folds and may be due, at least in part, to the intrusion of the younger plutonic masses of that district. Thus a number of minor folds south-west of Mt. Brothers can be seen to pitch almost vertically, the strike of the limbs being about 330° and 70° respectively, and that of the axial planes 110°.

Schistosity is always parallel to the bedding of the original sediments, as may be well seen in thin section 6625 (University of Melbourne collection), which contains alternating bands of contrasting composition. No foliation parallel to the axial planes of the folds is found in any of the recrystallized rocks, although slaty cleavage is strongly developed in the argillaceous sediments on either side of the metamorphic belt. The absence of this axial plane foliation is regarded as significant in assessing the relative importance of recrystallization and mechanical deformation in the metamorphism of these rocks, cf. Fairbairn (1935).

Schistosity parallel to the bedding can be developed by recrystallization alone (mimetic crystallization), but would be destroyed by intensive deformation, unless the beds were first folded isoclinally. The essentially igneous nature of the metamorphism is thus indicated, and is supported by the general parallelism of the various zones with the limits of the major gneissic intrusions within the belt, and by the presence in the inner zones of minerals characteristically developed only in the presence of volatiles and magmatic solutions. As pointed out by Tattam, it is contact metamorphism in the widest sense.

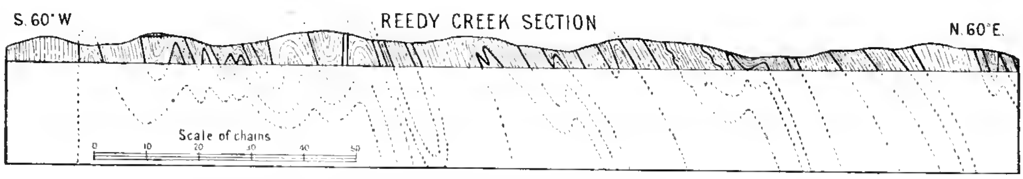


Fig. 3.—Reedy Creek Section.

Lineation as well as foliation is developed in many of the medium and high grade metamorphic rocks. Its inclination to the horizontal varies, but in the few instances where its relationships could be checked it was found to be parallel or sub-parallel to the axes of nearby minor folds, suggesting that it coincides with the *b*-direction (tectonic axis) of Sander. It may be due to minute corrugations of the schistosity planes, to the dimensional parallelism of inequidimensional grains or nodules, or to a combination of these factors (6703, 6704, 6626, etc.).

Jointing is not typically well developed, but occasionally two sets can be distinguished, as in the lower portion of Reedy Creek. There the dominant set corresponds to an (*h0l*) plane of Sander, i.e., parallel to the strike of the beds, but dipping at angles of 60° to 90° to the bedding planes. The spacing of this set varies irregularly and the joints occasionally pass into reverse faults of up to 4 ft. or 6 ft. displacement. The second set is represented by less numerous joints which, however, show a strong tendency to be concentrated in the vicinity of the fold axes. These are the *ac* joints of Sander, normal to the pitch of the folds. They are readily distinguished from the first group by their tendency to be infilled by veins of quartz up to 1 in. in width. These observations are consistent with the interpretation of the (*h0l*) joints as due to shear and the *ac* joints as due to tension (Sander 1930).

PETROLOGY

In a very general way, metamorphism can be regarded as increasing from north-east to south-west, as the main igneous contact of the area, extending from the Tongio Gap, south-east of Omeo, to the Big River valley, south of Mt. Bogong, is approached. The various zones are sub-parallel to this contact, but higher grade rocks surround many isolated masses of gneiss west of the main contact, as at Mt. Leinster and east of Mt. Bung Bung.

Low-grade Schists

The least altered sedimentary members of the Omeo series in the area are restricted to the north-eastern portion, where they outcrop at the previously mentioned Wombat Creek locality and in the Mitta Mitta valley, downstream from Four-Mile Creek.

To the south and east, these beds grade into others, in which distinct traces of shearing and incipient recrystallization can be recognized even in the hand-specimen. Such rocks form the dominant types in the eastern portion of Frazer's Tableland, to the north of Mt. Brothers and in the immediate vicinity of Benambra township.

Argillaceous beds have typically been more altered than their arenaceous counterparts, and show a tendency towards the development of sericite flakes in good parallelism over areas up to ·5 mm. in diameter, which may be the forerunners of the spots and nodules of the higher grade schists. The individual flakes, however, remain too small to be distinguished clearly (6627).

The more arenaceous types are usually strongly inequigranular, a fine-grained matrix being frequently present even in rocks containing a high proportion of grains over ·2 mm. in diameter. The majority of the coarser grains are sub-rounded and sub-equidimensional. They may consist essentially of quartz, but more commonly other minerals are also present in significant amounts. These may include clastic felspar, tourmaline, muscovite, biotite and magnetite. The state of preservation of all these minerals varies considerably, but in some of the specimens they are so fresh as to preclude the possibility of very extensive transport (6628).

Quartz veins are frequently very abundant, but do not usually exceed ·5 mm. in width. They may be arranged sub-parallel to the bedding or to a well-marked set of joint planes, or they may appear to intersect the rock in random directions.

Medium-grade Schists

With increasing grade of metamorphism, the rocks pass into the biotite zone, which covers a large proportion of the area and is especially well represented on the southern slopes of Mt. Bogong and in the headwater regions of Reedy Creek, Red Gap Creek and Wilson's Creek, all north-east of Omeo township. The incoming of the index mineral appears to be almost simultaneous in arenaceous and argillaceous beds, and, except for a progressive increase in the size of the individual flakes, no differences have been noticed between the biotites from different parts of this zone. The dark red-brown varieties are regarded as typical, and the frequent occurrence of pale brown or greenish-brown types is thought to be due to retrograde changes, being commonly associated with other evidence of decomposition or hydrothermal action (6629, 6630, etc.).

The primary constituents of most rocks in this group show no features of special interest, except for a series of specimens from the headwater region of Reedy Creek and Red Gap Creek (6631, etc.), in which finely grained graphite

becomes an important constituent. In the finer-grained, more argillaceous rocks the parallelism of the reconstituted micas is usually very well developed, but in the coarser-grained, arenaceous types the alignment may be much less complete (6630, etc.). Such rocks are more closely allied to the schistose hornfelses of Tattam than to true schists.

Cordierite-bearing Rocks

As the grain size of the reconstituted micas increases, the spots of incipient cordierite, which appear early in the biotite zone, tend to be more sharply defined. The incoming of this mineral, however, cannot be used to define a new zone, since it readily breaks down again to fine-grained aggregates of chlorite and white mica, which have been referred to as pinite by Tattam. These aggregates, due to retrograde changes, cannot be readily distinguished from those knots of micaceous and chlorite flakes which precede the formation of cordierite, except in a few cases, in which the crystal form or cleavage of the cordierite are preserved in the pseudomorph.

Cordierite is developed earliest and most abundantly in the more argillaceous beds, where it gives rise to subhedral crystals up to 5 mm. long, with their longest diameters, parallel to the *c*-axis, coinciding with the schistosity planes. Replacement by pinitic aggregates is usually more or less complete, but even in totally replaced crystals the external form and characteristic basal parting of the original mineral may be preserved, as in a specimen from the Knocker (6633). More commonly, however, the pinitic aggregates are elliptical, or lenticular, and the planes of schistosity of the matrix conform closely to their outlines. 'Tails' of quartz are frequently formed in the protected angles at the extremities of the nodules, and occasionally the nodules themselves may be intersected by narrow quartz veins (6633).

The pseudomorphs frequently show a layered structure, comparable to that described by Tattam in rocks from Mitta Mitta, alternate layers varying in grain-size and mineral contents. The finer-grained layers consist essentially of pinite in which the individual flakes are barely distinguishable, while the remaining ones contain various proportions of relatively large flakes of muscovite and biotite, up to ·5 mm. in diameter, scattered through a similar pinitic matrix. The arrangement of the larger flakes within the nodules may be haphazard or may be controlled by the original basal parting of the crystals (6635). Uniformly small rounded quartz granules, of average diameter ·05 mm., may also be scattered through the nodules, giving a characteristic 'sieve texture,' which is the equivalent of the original poikiloblastic texture of the cordierite.

A rather less common texture, comparable to one described by Broadhurst and Campbell from Mt. Leinster, can also be seen in the same rock (6635), from the southern slopes of Mt. Bogong. A rim of muscovite flakes around one of the nodules shows parallelism to the 001-parting of the original cordierite in its inner portion, but the flakes are curved so as to conform to the schistosity of the matrix near its outer edge. This, together with a tendency for the enclosed quartz grains of this nodule to lie on S-shaped curves, suggests that rotation of the porphyroblast took place during the final stages of its growth, i.e., para-crystalline deformation.

In the arenaceous equivalents of these cordierite-bearing rocks no significant development of new minerals, as compared to the earlier stages of the biotite zone, takes place at this stage. There are, however, a number of marked textural changes. Quartz shows obvious signs of recrystallization with the formation of outgrowths

in optical continuity with the primary grains (6636, 6637), and in the more inequigranular rocks the coarser grains may show undulose extinction, while the smaller ones extinguish cleanly (6638). Tourmaline shows signs of having been introduced or reconstituted in some of these rocks, but its distribution is highly irregular, apparently depending on local concentrations of the mineralizers involved in its crystallization. Clastic felspar, if originally present, is usually completely sericitized at this stage, and may be replaced by relatively coarse-grained micaceous aggregates (6639, etc.).

Cordierite is only rarely developed in these arenaceous rocks, forming irregular poikiloblastic or interstitial grains, which are typically less pinitized than their equivalents in the argillaceous rocks (6640, 6641).

A very characteristic feature of these rocks is the development of super-individuals of quartz, as is well shown by rocks from Wilson's Creek (6642) and Mt. Bung Bung (6643). In these specimens, strongly recrystallized quartz shows dimensional orientation which gives a slightly schistose appearance to the rocks, both in thin section and in the hand specimen. However, a large number of adjacent or sub-adjacent grains will frequently extinguish simultaneously, thus revealing the presence of 'super-individuals,' which are not necessarily themselves elongated parallel to the schistosity. Similar features have been described by Sander (1930) and Fellows (1943), but their interpretation is not yet clear.

High-grade Schists

On still closer approach to the main igneous masses of the metamorphic belt, evidence of recrystallization under the action of magmatic gases or solutions becomes very strong and appear to have outlasted the action of directed pressure.

Any original cordierite crystals or pinite nodules lose their sharp demarcation against the matrix and tend to enclose a higher proportion of relatively large euhedral flakes of both biotite and muscovite (6644, etc.). Tourmaline becomes very much more abundant and a second generation of white mica makes its appearance. This consists invariably of larger, strongly poikiloblastic flakes, up to 2 mm. in diameter, arranged in random crystallographic orientation, although they may show distinct elongation parallel to the schistosity of the rock as a whole. These flakes rarely show evidence of mechanical deformation. They are close to muscovite in having optic axial angles of 20° to 30°, but differ in showing slight pleochroism, pale brown to colourless, suggesting a slightly higher Mg- or Fe-content. As with cordierite, the development of these oblique micas is earlier and better in argillaceous than in arenaceous rocks. Various stages in their development can be observed in a number of specimens from scattered localities—for example, incipient growth (6645, 6646), fuller development (6647, 6648), and the extreme stage (6649).

Rocks showing these phenomena are especially well developed in the lower portion of Red Gap Creek, east of Omeo, and in the Big River valley between Mt. Bogong and Mt. Nelse.

Sillimanite Schists

Sillimanite is restricted to rocks occurring very close to major igneous contacts, but its first appearance cannot be used to define a zone in the field, since its development is frequently intensely localized. It may develop either in quartz, as isolated needles or radiating aggregates, or in biotite as dense bundles of fibres.

These fibres may almost or completely replace the host biotite and may develop into thicker rods, with characteristic transverse parting. Rocks from Red Gap Creek (6650, 6651), Mt. Bogong (6652) and Mt. Wills (6653) show these phenomena. Similar observations were recorded by Tattam in schists from the northern part of the metamorphic belt.

The extremely localized nature of these changes is well shown by a rock from Mt. Bogong (6654, 6655). Here, sillimanite is replacing a rock characterized originally by the presence of poikiloblastic muscovite and cordierite. The latter occurs as irregular grains and crystals, up to 1 cm. in diameter, which enclose quartz granules, small euhedral biotite flakes, and also some of the relatively coarser muscovites. The change begins with the fibrolitization of the biotite, but ultimately involves all the other above-mentioned minerals, the final product being an aggregate of almost pure sillimanite and the change being complete within the dimensions of a thin section.

Felspathic Schists

Poikiloblasts of alkali felspar occur in a number of specimens, including the last-described, but their relationships are best shown in a rock from T-spur, in the Big River valley (6656). In the hand specimen, this rock has a characteristic appearance due to the development of two generations of 'spots'. The first, due to the original poikiloblasts of cordierite, now represented by fine-grained micaceous aggregates up to 8 mm. in diameter and enclosing numerous minute quartz granules, are poorly defined and darker than the main mass of the rock. The second, consisting of irregular poikilitic alkali felspars, do not exceed 1 mm. in diameter, but are sharply defined and lighter in colour than the surrounding matrix. In the absence of chemical analyses, it is not possible to assert definitely the magmatic origin of this felspar, but the textures and field relationships of these rocks very strongly suggest such an explanation.

A rather different type of contact phenomenon characterizes the Dry Creek-Three-Mile Creek area, to the south and west of Omeo township. Here, bands and lenticles of schist which have undergone extreme recrystallization and possibly addition of igneous material, are intercalated with augen gneisses due to the mechanical deformation of originally massive igneous rocks. A typical specimen from Mountain Creek (6657) has preserved the sedimentary alternation of argillaceous and arenaceous bands with an average thickness of 2 to 5 mm. The argillaceous bands consist chiefly of sericitic aggregates, slightly bleached biotite and occasional muscovite, while the arenaceous bands are composed almost entirely of quartz and felspar. The latter apparently belongs to two distinct generations, one completely sericitized and often sub-rounded, suggesting clastic origin, the other clear, typically strongly zoned, often rich in enclosed granules of quartz. Occasionally a sharply defined sericitized core is surrounded by a clear rim, suggesting a moulding of the introduced felspar on the older clastic grains. Pyrite has also been introduced into this rock.

Similar relationships are shown by rocks from Dry Gully (6658) and Livingstone Creek (6659), the latter in addition showing again the development of 'super-individuals' of quartz elongated obliquely to the schistosity. These rocks are the equivalents, on a small scale, of the 'granular gneisses' which form one of the major rock types of the Bogong High Plains and which will be discussed in detail in a later section.

Older Intrusives

The older intrusives of the area, comprising the gneisses of the Omeo Series and their massive plutonic equivalents, are the dominant rock types to the south-west of a line passing from the Tongio Gap, south-east of Omeo, to the Big River valley between Mt. Bogong and Mt. Nelse. Isolated stocks of the igneous rocks do occur to the north and east of the line, notably in the Mt. Leinster district, and there are a number of inliers of schist among the dominantly igneous rocks to the south and west, but the main contact is clearly defined for the greater part of its length.

Howitt (1887) mapped the southern portion of this contact as a fault junction and described it as a line, along which the schists had been let down into a magma chamber. However, even if such a movement had occurred, for which there is no direct evidence, the original fault junction would have been obliterated by the metamorphism and partial assimilation resulting from the juxtaposition of the magma and the sediments, so that the present boundary is best regarded as a normal intrusive contact.

In the area as a whole, rock types can be found to illustrate every stage of the series from massive igneous rocks to strongly gneissic types, and the latter can be further subdivided according to the relative importance of contamination, recrystallization and mechanical deformation in their development. Wherever contrasting types are directly in contact, as in Rocky Valley, Pretty Valley and in Livingstone Creek near the junction of Three-Mile Creek, the massive rocks can be seen to be the youngest members of the series, transgressing the banded structures of the gneisses, and locally giving rise to apophyses which penetrate the gneisses for a distance of a few feet, usually parallel to the foliation.

Granodiorites make up the great majority of the massive intrusions, but one occurrence of granite and one of quartz diorite are included in this group because they show similar structural and field relationships.

Granodiorites

Granodiorites have been examined from Day's Creek, Livingstone Creek, Frazer's Tableland, Rocky Valley and Mt. Leinster. Heavy mineral analyses of these and other rocks described are given in Table 1 and Rosiwal analyses in Table 2.

The occurrence from Rocky Valley and Basalt Hill (6665, 6666) may be regarded as typical of this group. It is a light grey, medium-grained, even-grained rock, showing no banding or parallel arrangement of any of its constituents. Andesine, Ab_{65} to Ab_{60}, is the dominant felspar, occurring as squat, subhedral crystals up to 2 mm. long, typically strongly zoned and frequently showing sharply defined sericitized cores surrounded by clear rims. Orthoclase occurs as larger, less numerous, irregular grains, poikilitic towards all the other minerals present. Biotite forms sub-rectangular flakes, up to 2 mm. long, occasionally with pleochroic haloes, typically deep greenish brown in colour, occasionally chloritized. Muscovite occurs as rather less abundant and less regular flakes, either independently or in close association with biotite.

Quartz forms irregular grains, up to 2 mm. in diameter, tending to be interstitial in habit and frequently enclosing small plagioclase crystals and biotite flakes or moulded on larger individuals. Epidote, magnetite and apatite are the most important minor constituents.

The least recrystallized rocks from Livingstone Creek are closely comparable to the above, except for a slightly higher content of chlorite and epidote and the presence of a few pinitic aggregates up to 1 mm. in diameter, which may represent original cordierite crystals (6663). Here, however, such rocks grade into those showing the first traces of recrystallization (6662). The quartz tends to be recrystallized with the formation of interlocking grains showing crenulated boundaries against one another, and a slight tendency towards a parallel arrangement of the biotite flakes can be detected in the hand-specimen. Rocks which have suffered a comparable amount of recrystallization also occur in the Mitta Mitta valley near the junction of Four-Mile Creek (6664), and at the head of the Bundarra River near Mt. Jim (6668).

A slightly more advanced stage of recrystallization is displayed by rocks from Mt. Nelse (6669), and from Dry Creek, west of Omeo (6670). In these specimens biotite has been affected, as well as quartz, the larger flakes being frequently distorted and the smaller ones being obviously aligned in layers which curve around the larger felspar crystals and the aggregates of recrystallized quartz. Bleaching and chloritization of the biotite are more advanced in these rocks than in the comparable massive types, and the proportion of epidote is distinctly higher.

Quartz Diorite

The only hornblende-bearing plutonic rock in the area to be correlated with the granodiorites is a quartz diorite from the lower portion of the Bundarra River valley (6672). Euhedral to subhedral andesines, Ab_{60}, up to 1 mm. in diameter, show strongly sericitized cores and are occasionally zoned. Brown biotite forms irregular flakes, up to 2 mm. in diameter, frequently bleached and occasionally replaced by epidote. Hornblende is present in about equal amount, typically as slightly smaller, rather ragged prisms, pleochroic brownish-green to bluish-green, occasionally chloritized. Magnetite is rather abundant as relatively coarse cubes and octahedra, associated in one case with subordinate pyrite. Quartz is restricted to interstitial grains and occasional pools, up to 5 mm. in diameter, in which any of the other minerals of the rock may be enclosed.

Similar rock types have been described by Howitt from Dargo (1887) and from Swift's Creek (1879), and by Tattam from Yackandandah. They are intermediate in mineral composition, and probably in age, between the granodiorites and the lamprophyric diorites to be discussed below, and they will be referred to again in connection with the latter.

Granite

The only alkalic plutonic rock in the area definitely associated with the older intrusives is a garnetiferous granite, outcropping over a distance of about half a mile in the valley of Livingstone Creek, about five miles north of Omeo township. It includes both massive and faintly banded types, which, however, do not differ essentially in mineral composition. In a typical specimen (6673), soda-orthoclase of $2V = 60°$ occurs as pools up to 5 mm. in diameter, enclosing any of the other essential constituents of the rock, which are quartz, oligoclase (Ab_{75}), muscovite and biotite in that order of abundance. The garnets are represented by scattered euhedral crystals, up to 1 mm. across, occasionally enclosed by orthoclase or surrounded by muscovite which tends to wrap around them.

This rock might have been derived from the more common calc-alkali types by contamination with K- and Al-rich material, but the even distribution of the garnets

suggests that if any assimilation has occurred its products were already evenly distributed through the mass at the time of recrystallization. Its contacts with surrounding gneiss are poorly exposed.

Gneisses

The gneisses of the area may conveniently be divided into three classes. To the first belong those which are essentially sheared granodiorites and granites. To the second belong rocks which were originally granodiorite or granite but have been recrystallized. These are characterized by relative abundance of muscovite. The third class includes those gneisses containing sillimanite or cordierite, or both. Its members range from rocks which are essentially contaminated granites and granodiorites to fine-grained granular siliceous gneisses derived mainly from sedimentary rocks. The three classes are not sharply defined one from another.

Sheared Granodiorites and Granites

In the rocks which have suffered mechanical deformation with only moderate amounts of recrystallization, parallelism of the inequidimensional minerals, usually without marked banding, is the rule. Owing to the very unequal resistance of the various minerals to shearing, augen gneisses are frequently developed under these conditions.

The various stages of this process are well shown by a group of specimens from a shear zone, about one mile wide, which runs N.N.W.-S.S.E. through the headwater regions of Dry Creek and Mountain Creek, across the north shoulder of Mt. Livingstone and along the northern slopes of Three-Mile Creek. The maximum diameter of the augen, which varies between 2 and 5 mm. in different specimens, depends largely on the original grain-size of the rock, and decreases only very slightly with more intense shearing. The quartz and biotite of the matrix, on the other hand, show a progressive decrease in grain-size from an average of ·5 mm. (6661) to ·05 mm. (6674, 6675). At the same time, the biotite shreds are aligned more accurately within the planes of schistosity, which conform closely to the lenticular outlines of the augen, and their finer subdivision gives a darker appearance to the hand-specimen as a whole. The augen may be composed of single andesine crystals, Ab_{65} to Ab_{55}, or of aggregates of quartz developed from a single grain by recrystallization. In the latter case, the size of the individuals within the aggregates tends to be comparable to that of the grains of the matrix. The felspar is typically strongly zoned (6675, 6676), a combination of normal and oscillatory zoning being commonest. They may also be fractured and the fragments displaced by distances of the order of 1 to 2 mm. relative to each other. Their outline becomes more markedly lenticular in the more strongly deformed rocks (6677, etc.), and the more elongated ones tend to be rotated into a position with their longest diameters parallel to the schistosity of the matrix. Since most of the crystals are tabular parallel to the crystallographic *a-c* plane, this also results in a preferred lattice orientation, which thus does not necessarily indicate intra-granular movement.

This shear-zone, which is approximately parallel to the main schist-gneiss contact of the area and to the dominant local strike of the foliation in both schists and gneisses, appears also to have acted as a major solution channel, since pyrite has been introduced into many of these rocks and a number of formerly productive gold workings are situated along it. There has resulted sericitization of the felspars

and chloritization of the biotite of some of the rocks (6679, 6680), and development of relatively abundant epidote or white mica in others (6681, 6698).

Some rocks have undergone both shearing and recrystallization. In such cases the time relationships between recrystallization and mechanical deformation can rarely be established, since the last process to persist usually obliterates all traces of the earlier ones. However, a specimen from Mountain Creek (6682) is exceptional in preserving traces of two periods of deformation. It contains porphyroblasts of slightly perthitic orthoclase in a matrix consisting of lenticles of recrystallized quartz and sericitized felspar, separated by streaks of chloritized biotite. The matrix corresponds to an augen gneiss derived from a massive igneous rock by strong shearing, although the high biotite content indicates some original contamination. The porphyroblasts contain inclusions of quartz granules and parallel orientated biotite flakes, which, however, have been rotated out of the plane of schistosity of the matrix. They were thus formed subsequently to the shearing of the rock, but were themselves rotated during a second, less intense, period of deformation.

In a rock from the Alpine Highway (6683), recrystallization after the cessation of movement can be shown to have been restricted to the crystals of andesine, Ab_{60}, which form augen in a matrix of quartz lenticles and sub-parallel flakes and shreds of biotite. These crystals show a clear core, surrounded by an outer zone with abundant inclusions of quartz granules and biotite flakes, orientated similarly to those of the matrix, indicating that their growth continued after the shearing responsible for the present gneissic texture of the rock had ceased.

Recrystallized Granodiorite and Granites

Gneisses derived from originally homogenous massive plutonic rocks by recrystallization without significant shearing are comparatively less abundant, but provide a number of interesting types throughout the area.

Two specimens from Wilson's Creek (6684) and from the Omeo-Benambra Highway (6685) illustrate the early stages in the development of these rocks. They are characterized by the presence of perthitic orthoclase as irregular grains, up to 3 mm. in diameter, rich in inclusions of quartz blebs and small biotite flakes, and of subordinate oligoclase, Ab_{75}, as smaller sub-rectangular crystals. Quartz is represented by aggregates up to 3 mm. in diameter composed of numerous interlocking individuals, and the rock from the second locality also contains occasional grains of original cordierite, now represented by pinitic aggregates. Biotite forms medium-sized flakes, originally deep reddish-brown, but frequently chloritized or bleached, and shows no preferred orientation. The most distinctive feature of these rocks, however, is the very abundant development of muscovite, which initially replaces biotite or felspar, and finally forms strongly poikilitic flakes, up to 2 mm. in diameter, which enclose numerous small quartz granules and minor amounts of any of the other minerals present in the rock.

Comparable rocks also occur in the western portion of the area, a group of specimens from Rocky Valley being fairly typical (6686, 6687, etc.). These are inequigranular rocks characterized by the presence of phenocrysts of subhedral, strongly zoned andesine, Ab_{55}, or oligoclase, Ab_{70}, which may enclose quartz granules or biotite flakes in their outer zones. Orthoclase forms subordinate interstitial grains or small pools, while quartz is abundant as medium-sized irregular grains and shows only slight evidence of recrystallization. Biotite occurs as small irregular flakes, either singly or in clots, and may be extensively replaced by

chlorite or epidote, or both. Muscovite forms larger but less numerous flakes and tends to be poikilitic. No sillimanite or cordierite are present in the majority of these rocks.

Cordierite-Sillimanite Gneisses

These rocks predominate in the western part of the area and are only sparsely represented in the eastern and central parts. The processes of contamination and recrystallization under the action of late magmatic solutions or emanations have both operated during their development and the effects of these processes are not easily distinguishable.

The gneisses typical of the High Plains are invariably strongly heterogeneous rocks, in which banding or parallelism of the constituents are inherited from the assimilated or replaced sediments, and are not due to post-crystalline deformation. In thin sections, they are characterized by the presence of cordierite or sillimanite, or both, and in the field by the occurrence of irregular biotite-rich schlieren and of quartz-felspar nodules up to six inches in diameter. The former represent remnants of the engulfed sediments and frequently preserve primary structures in remarkable detail, while the latter are the extreme development of the felspar poikiloblasts commonly present in these rocks. These nodules may be composed essentially of one or more of quartz, perthitic orthoclase or andesine, average Ab_{65}. Micrographic intergrowths and myrmekite may occur at the contacts of quartz and felspar grains, and very occasional flakes of muscovite or biotite may also be present in the nodules. They are always surrounded by sheaths of almost pure biotite as relatively large flakes in good parallelism, suggesting that they resulted from the partial reconstitution of the original rock, during which the femic constituents were eliminated and re-precipitated in the immediate vicinity.

Two specimens from Mt. McKay (6688) and the road to Rocky Valley (6689) may be regarded as typical of this group. In the latter, andesine (Ab_{60}) is the dominant felspar, occurring as irregular crystals up to 2 mm. across, while perthitic orthoclase, as pools up to 10 mm. in diameter, predominates in the former. Quartz is the major constituent and occurs as medium-sized, irregular grains without marked evidence of recrystallization, and grains of original cordierite show various stages of alteration to micaceous aggregates or to a yellow, isotropic material. Biotite occurs as irregular flakes, without noticeable parallelism, but tending to be concentrated into bands or streaks, while muscovite forms isolated, rather larger flakes, typically strongly poikilitic. Sillimanite is invariably present, occurring as dense bundles of sub-parallel fibres when derived from biotite or as isolated needles and radiating aggregates when developed in quartz.

The nearest approach to these rocks from the central portion of the area is provided by a cordierite-sillimanite gneiss from Bingo Creek (6691) and a tourmaline-sillimanite gneiss from Day's Creek (6692), both with poikilitic muscovite and pools of alkali felspar.

Within the major masses of the High Plains type of gneiss, finer-grained gneisses richer in biotite form large schlieren and lenticles, outcrops up to 100 yards in width and half a mile in length being not uncommon. These rocks are transition types from the contaminated gneisses to the high-grade schists and some of them could equally well be classified with the latter. They differ from the typical High Plains type of gneiss in their higher biotite contents and better parallelism of the micas, accompanied usually by an increase in sillimanite and a rise in the proportion of quartz to felspar (6693, 6694).

An interesting specimen from Mt. Cope (6695) shows the preservation of small puckers of about one inch amplitude in a rock of this type. The folds are now outlined by alternate layers, composed dominantly of igneous and of sedimentary material respectively. The latter are composed mainly of biotite and sillimanite with subordinate muscovite and quartz, while the former consist essentially of quartz, poikilitic muscovite and alkali felspar, the last-named forming pools which may enclose any of the other minerals, and occasionally occurring in micrographic intergrowth with quartz. The absence of post-crystalline deformation is very clearly shown by the euhedral outlines of the biotite at the crests of the folds and by the absence of undulose extinction in the quartz.

This type of gneiss grades imperceptibly into what may be termed granular gneisses, in which sillimanite is generally absent and parallelism of the micas less marked. Lower temperature and a different physical environment at the time of reconstitution may partly account for these characteristics, but derivation from arenaceous sediments, as against argillaceous sediments for the sillimanite and biotite-rich rocks, is the main factor. Tattam called them granulites, but granular gneisses seems preferable, as they do not appear to have originated under conditions of extreme hydrostatic pressure which are thought to have characterized the development of the typical granulites in other parts of the world (Turner 1948). They illustrate various stages in the reconstitution of the original sediments by the actions of solutions or emanations, which deposited quartz and felspar, either in small clots and lenticles, or as isolated crystals, distributed uniformly through the rock. In the absence of chemical analyses, it is not possible to establish whether these newly crystallized constituents were actually introduced from nearby bodies of magma or were merely redistributed by continuous processes of solution and re-deposition as the 'ichor' made its way through the sediments. In view of the very large volume of sediments affected by these changes, the latter hypothesis, or possibly a combination of the two would appear probable.

Both banded and massive types can be recognized, frequently alternating very irregularly. The resultant complexes occupy large areas on the flanks of the major occurrences of gneisses of the High Plains type, as in the lower portion of the Rocky Valley branch of the East Kiewa River, and in the middle portions of the Bundarra River and Middle Creek valleys.

A typical specimen from Rocky Valley (6696) contains alternating discontinuous bands composed respectively of quartz and sub-parallel biotite with subordinate andesine and muscovite, and of relatively coarser-grained quartz and andesine, Ab_{65}. The quartz shows evidence of recrystallization under directed pressure, but the micas are free from any signs of deformation or alteration.

Correlation and Age Relationships

The general picture of time relationships and processes of intrusion and metamorphism is in good agreement with observations elsewhere in the metamorphic belt, notably in the Tallangatta and Yackandandah districts. The earliest intrusions were emplaced by processes of granitization, resulting in large areas of gneisses of the High Plains type, flanked by zones of hybrids and granular gneisses in which the reconstitution of the sediments was less complete. Beyond these again, the sediments were extensively recrystallized to two-mica schists and nodular cordierite schists, in which the local development of sillimanite and reconstituted felspar marks areas of abnormal concentration or activity of the volatiles or solutions from

the igneous masses. The attitude of the sediments was substantially preserved during the formation of the hybrids and injection gneisses, showing that the emplacement of these igneous rocks was effected by the soaking of the sediments by magmatic solutions or emanations, rather than by the forcible injection of the more viscous magma itself. (Compare Demay 1942, Dunn 1942, etc.)

Subsequent phases of igneous activity gave rise to massive rocks with sharp, transgressive contacts against both schists and gneisses. Whenever these were intruded into previously unmetamorphosed sediments, as on the west slopes of Frazer's Tableland, contact aureoles of hornfels rather than of schist were produced. These intrusions themselves, however, were still affected by localized tectonic stresses, such as those responsible for the production of augen gneisses in the Dry Gully - Three-Mile Creek shear zone, and by recrystallization under the action of local concentrations of volatiles, as in Day's Creek.

The time interval between these two major groups of intrusions cannot be established definitely. Both phases are post-Upper Ordovician, since rocks of that age are involved in the first (or regional) cycle of metamorphism. On the other hand, intrusions of the second phase are overlain unconformably by lavas and limestones of Middle Devonian age at Bindi, which set an upper limit to their possible age.

Rocks comparable to the High Plains type of gneiss have been described from southern New South Wales by Joplin (1947), who refers them to an epi-Ordovician orogeny, as contrasted with an epi-Silurian age for the massive granites and granodiorites associated with them. In the Omeo district, such a complete separation appears unwarranted, since intermediate types, representing various stages in the transition between the two extreme groups, can frequently be observed, especially in the vicinity of the main schist-gneiss contact.

Muscovite Granite of Mount Wills

The muscovite, or pegmatitic, granite of Mt. Wills is a striking rock, which crops out intermittently in a belt about twelve miles long and six wide, extending north-westerly from Glen Wills to a point about four miles east of Mt. Bogong. At its southern and eastern boundaries it forms a number of steep slopes and escarpments, but its physiographic effect is less marked near its western extremity.

It may be regarded as a batholith crowded with major roof pendants, up to half a mile in diameter, which cover a total area comparable with that of the granite itself. It is considered to be the product of one of the final phases of that cycle of igneous activity which was responsible for the grey granites, granodiorites and gneisses, but in the absence of direct contacts its relationships can only be inferred on general grounds. The lower limit of its age is given by the fact that its contact metamorphism is superimposed on schists which had already suffered high grade regional metamorphism, showing that it post-dates at least the first phases of the main group of gneissic intrusions. An upper limit is set by the numerous dykes of the dioritic lamprophyre group to be discussed later, some of which cut the pegmatites and greisens correlated with the Mt. Wills mass (Kenny 1925a, Whitelaw, Kenny and Easton 1915). These dykes are probably Upper Devonian or slightly younger.

Petrology

The rock varies from medium to very coarse-grained, frequently within the dimensions of a hand-specimen, but the mineral association is relatively constant.

In the north-western part, the less coarse-grained types predominate and the rock contains both biotite and muscovite. A typical section (6699) shows abundant orthoclase with numerous rounded blebs of quartz as inclusions, subordinate subhedral oligoclase (Ab_{85}), usually strongly sericitized, and abundant strongly recrystallized aggregates of quartz. Biotite forms scattered small flakes, but muscovite is more abundant, occurring as larger poikilitic flakes, faintly pleochroic, frequently distorted. Tourmaline, pleochroic dark brown to light brown, is relatively abundant, occurring typically in intergrowths with quartz.

In the south-eastern portion of the mass, the coarser-grained types are more abundant and a number of features indicate that the rocks were exposed to high concentrations of volatile constituents during the last stages of consolidation. Albite, Ab_{95}, is the dominant felspar, forming strongly sericitized, subhedral crystals up to 5 mm. in diameter, while the original alkali felspar is partly replaced by bluish and greenish-grey tourmaline aggregates and occasional topaz granules, or by small irregular grains of calcite (6697, 6715). Quartz again forms recrystallized aggregates, but the poikilitic character of the muscovite is less marked and biotite is absent. Pyrite is abundant as small cubes and other euhedral crystals, developed in felspar or in quartz aggregates. Occasionally, tourmaline-rich pockets within the rock contain up to 30 per cent of this mineral as small needles or prisms, up to 1 in. in length, usually in association with quartz and felspar, but not with muscovite.

Gneissic types are rare amongst these rocks, but a specimen from half a mile east of the summit (6700) shows distinct banding and parallelism of muscovite and tourmaline.

Contact Rocks

The increase in grain-size and in the proportion of tourmaline, topaz and sulphides is accompanied by an increase in the contact metamorphic effects of the mass at its south-eastern extremity. In the north-western and central portions, metamorphism was restricted to the introduction of tourmaline into the argillaceous bands of the surrounding schists. This was followed by the growth of poikiloblastic flakes of muscovite, but both these changes post-dated the development of sillimanite, which is thought to belong to an earlier period of metamorphism, unconnected with the intrusion of the Mt. Wills mass.

In the vicinity of the south-eastern contacts reconstitution was much more complete, as shown by many specimens from mine dumps. Originally arenaceous beds are still essentially quartz-biotite rocks with good schistosity and only minor amounts of muscovite and tourmaline (6701, 6702), but several characteristic types of contact rock were developed from originally argillaceous beds. One of these (6703, 6704) is a fine-grained rock with well defined schistosity which has been thrown into small puckers of 1 to 2 mm. amplitude. It is composed essentially of small muscovite flakes in almost perfect parallelism, evenly distributed prisms of brown tourmaline, quartz granules and subordinate, rather poorly defined flakes of biotite. Sulphides are scattered through this rock as isolated small crystals, but never in very large quantities.

Another group of rocks (6705, 6706, etc.) is of interest as the only specimens of sedimentary origin in the area to contain andalusite. This mineral occurs as irregular grains, up to 3 mm. long, elongated parallel to the schistosity of the matrix, and readily identified by its very characteristic pink-colourless pleochroism. The crystals are crowded with inclusions of quartz granules, small biotite flakes and

tourmaline prisms, all aligned parallel to the schistosity of the matrix. Occasionally these andalusites are coarsely intergrown with large, almost equidimensional flakes of strongly poikiloblastic muscovite, which pervade the rocks almost independently of the schistosity. The development of these two minerals, together with the introduction of occasional small tourmalines and scattered porphyroblasts of alkali felspar, clearly dates from a later phase of metamorphism than the reconstitution of the main mass of the rock, which is composed essentially of granular quartz, fibrolitized biotite and small muscovite flakes in good parallelism. This would suggest that andalusite requires rather higher temperatures or higher concentrations of volatile constituents for its formation than were available elsewhere in the area.

A related specimen (6707) is notable for the very marked preservation of the original sedimentary banding, being composed of sharply defined alternating light and dark layers which vary in width from about $\frac{1}{8}$ in. to 1 in. or more. The light or arenaceous bands consist of quartz and poikiloblastic cordierite as irregular crystals up to 1 mm. in diameter, together with abundant, poorly crystallized, bleached and strongly chloritized biotite and subordinate subhedral muscovite, the last two minerals showing fair parallelism, especially at the margins of the arenaceous bands. In the dark or argillaceous bands, andalusite occurs as irregular, strongly poikiloblastic individuals, up to 3 mm. in diameter, enclosing numerous small quartz granules, biotite flakes, etc. The remaining minerals in order of abundance are strongly pleochroic brown biotite, irregular to sub-rounded quartz, and occasional slightly poikiloblastic cordierite in various stages of replacement by pinite. Schistosity is not well shown in these bands, the micas tending to be aligned around the larger andalusites rather than parallel to the boundaries of the bands, and there is no evidence of mineralization or introduction of constituents from the nearby igneous rock.

A different mineral association again is shown by a specimen from a point about three-quarters of a mile E.N.E. of the summit, where it forms a xenolith or small roof pendant, measuring a few feet in diameter (6708). This rock consists dominantly of white mica, not unlike that from the surrounding granite, forming sub-parallel flakes up to 3 mm. by 1 mm., pleochroic pale greenish-brown to colourless, $2\,V = 30°$. In addition, it carries about 10 per cent of pale pink garnet as euhedral crystals up to 2 mm. in diameter, typically free from alteration but containing occasional small quartz granules and mica flakes as inclusions. The only other mineral present is zoisite (?), which makes up 1 per cent to 2 per cent of the rock, forming subhedral crystals up to 2 mm. in diameter, subject to clouding and alteration. Such garnet-rich assemblages have been described by Edwards (1936) as characterizing ferromagnesian-rich xenoliths at an early stage of interaction with a granitic magma, but in this case the homogeneity of the rock and the absence of granitic minerals indicate that the action of heat and volatiles alone must have been responsible for its reconstitution.

Ore Deposits

The general enrichment in volatiles of the south-eastern portion of the mass is reflected in the increased number and importance of workable gold and tin deposits in that vicinity. The former are in the nature of sulphide-bearing quartz veins, concentrated in a comparatively narrow belt parallel to the main granite contact, while the latter occur as pockets and lenticles of greisen, both within the

main mass of the granite and in the associated pegmatite dykes, which are rather more widespread in occurrence. Thus comparable rock types from the Mitta Mitta district have been correlated with the Mt. Wills granite by Whitelaw, Kenny and Easton (1915), and similar deposits from Wombat Creek have been recorded by Stirling (1889).

Dyke Rocks

Only a few of the dykes mapped during the present investigation can be definitely correlated with the Mt. Wills granite, the most important of these being the tourmaline pegmatites, muscovite pegmatites and graphic granite dykes of Mt. Bogong, the Knocker, etc. These range up to 20 feet in thickness and can sometimes be traced for long distances, their strikes tending to coincide closely with those of the surrounding sediments. They show no features of special interest, but are rather variable in texture and in mineral contents. Perthitic orthoclase usually predominates over acid oligoclase, Ab_{80} to Ab_{90}, the former frequently occurring as crystals several inches in diameter, especially when intergrown with quartz. Tourmaline may occur as large, well developed prisms, up to 3 in. long, as sub-parallel or radiating aggregates of smaller prisms and needles, or as irregular aggregates intergrown with quartz or replacing felspar. The larger prisms are frequently fractured at right angles to their long axes and the cracks infilled by quartz. Muscovite is best developed in rocks poor in tourmaline, occasionally forming books up to 1 in. square. All gradations between the various major types can be observed, but no rocks containing any of the less common minerals sometimes associated with pegmatites were found.

Pegmatites, Aplites and Granitic Dykes

At greater distances from the Mt. Wills mass, rock types comparable to the pegmatites and graphic granites associated with that intrusion are still met with, but they occur with less characteristic types, such as aplites, and tend to form lenticular masses rather than well defined dykes. They are concentrated in two main areas on the flanks of the main gneissic intrusions. One is a belt, six to eight miles wide, which extends approximately from the Tongio Gap to Glen Valley township in the centre of the area, while the other covers the lower portion of the East Kiewa valley in the extreme western portion. Within the area occupied mainly by gneisses of the High Plains type, they are relatively rare, and it is probable that their place is taken by the previously described leucocratic nodules in these gneisses, which would account, cumulatively, for a comparable volume of acid differentiates.

It is not usually possible to correlate any of these dykes with particular plutonic masses, but their relative ages can sometimes be established by comparing the amount of recrystallization which they have undergone. They are sometimes difficult to separate from the younger group of dykes associated with the Red Granite orogeny, but the latter appear to be restricted to an area relatively close to the main mass of the Red Granite and frequently show mineralogical peculiarities which assist in their identification. In addition, the acid differentiates of the older group frequently form rather larger masses and tend to grade into the adjacent ortho-gneisses instead of showing transgressive relationships to them.

Tourmaline-bearing types are not very abundant in this group, notable exceptions being a pegmatite from Bingo Creek (6709, 6710) and a more strongly

recrystallized rock from Livingstone Creek (6711). The former also contains a number of small subhedral garnets enclosed in larger grains of slightly perthitic orthoclase, suggesting a possible relationship to the garnetiferous granite of Livingstone Creek.

By a decrease in the amount of mica present, these pegmatites grade into veins of graphic granite, comparable to those already described in connection with the Mt. Wills granite. The extreme types are represented by rocks in which individual orthoclase crystals attain an average diameter of several inches and the enclosed quartz blebs are in optical continuity over comparable areas (6712, 6713, etc.).

Another very important type is represented by rocks which are most conveniently referred to as coarse-grained aplites, since they are characterized by the mineral association and texture of aplites, although the average grain-size may reach 2 mm. or more. A rock from the S.E.C. road to Rocky Valley (6714) illustrates this type. It contains perthitic orthoclase, acid oligoclase, Ab_{85}, and quartz in approximately equal amounts, together with rather less abundant muscovite, all the constituents occurring as equant, anhedral grains of about equal size.

With increasing amounts of recrystallization, these rocks grade into types which can only be distinguished from the major masses of granular gneiss by the absence of contamination effects, by the composition of their felspar, which is albite (Ab_{90} to Ab_{95}), and by their more homogeneous appearance in large outcrops. Two rocks from Wilson's Creek are of this type (6716, 6732), differing from the previous one essentially in the presence of small chloritized biotite flakes in about equal amounts to the muscovite, and in the incipient recrystallization of the original quartz individuals to aggregates of smaller grains.

Similar relationships hold in the case of the finer-grained aplites, the more strongly recrystallized equivalents of which locally form relatively large masses, as on the north shoulder of Mt. Livingstone and on the spur running north-west from Timm's Lookout. At these localities, recrystallized aplites outcrop over areas of at least half a mile by half a mile and the occurrences appear to date from one of the earlier phases of the igneous cycle.

One of the specimens from the former locality (6717) is notable for the presence of andalusite, which occurs as clusters of small platy and prismatic crystals closely associated with flakes of biotite in various stages of bleaching, or as isolated crystals enclosed by large alkali felspars. A specimen from a smaller outcrop in Mountain Creek (6718) also contains andalusite, originally occurring as crystals up to ·5 mm. long, but now partly altered to fine-grained aggregates of white mica.

Hills (1938) has suggested that andalusite may, under certain conditions, crystallize from an uncontaminated magma, but since there is here abundant evidence of contamination in many of the associated plutonic rocks, these occurrences of andalusite are probably due to the assimilation of aluminous sediments by the hypabyssal rocks concerned. The derivation of the mineral from xenocrysts is excluded by its complete absence from the country rock in the vicinity of these intrusions.

Another group of rocks which may be classified with the above is represented by a granite (6719) and two granodiorite dykes (6720, 6721), which form small masses in the lower portion of Day's Creek. These rocks are similar in thin section to specimens of the slightly recrystallized plutonic rocks from some of the larger occurrences, but their appearance in the hand-specimen is characteristic. The granodiorites especially, being composed essentially of clear quartz, deep-green chloritized biotite and pink to flesh-coloured felspar, present a striking colour

scheme. Mineralogically, their main distinguishing feature is the presence of unzoned, rather strongly sericitized albite, Ab_{90}, side by side with zoned, less altered oligoclase, Ab_{70}, the former occurring as larger but less numerous crystals than the latter, so that their total amounts are approximately equal.

Tambo Formation

General

The Tambo Formation of reddish and purplish shales, sandstones and conglomerates occupies an area of approximately six miles by four miles, elongated in a north-south direction and centred on the peak from which it takes its name. It was first described by Selwyn (1866), who recorded indistinct plant impressions from it, and more detailed accounts of its lithology and field relations were given by Howitt (1876) and Gaskin (1942). Only the northern portion of the occurrence was studied during the present investigation, but a number of new relationships were observed and new interpretations were given to several features previously observed by other workers.

The various lithological types alternate rapidly, individual beds varying widely in thickness and occasionally reaching 30 ft. to 40 ft. in the case of the coarser conglomerates. The dominant pebbles and boulders, which range up to 18 in. in diameter in some of the beds, are quartzite and reef quartz, with schists subordinate and igneous rocks almost absent, except in the basal conglomerate to be described below. The grits are characterized by poor sorting of the grains according to size and by the abundant presence of angular quartz (6722). Even the finest grained shales contain scattered angular quartz grains, and all indications are for rapid sedimentation under comparatively shallow-water conditions.

The strikes of the beds remain sensibly constant throughout the northern portion, varying between 340° and 360°. The dips are likewise uniform for the major portion of the series, ranging from 30° to 50° to the west and south-west, and showing a gradual increase from east to west. In the extreme west, however, approaching the contact with the granite porphyry of Mt. Sisters, the dips increase more rapidly and the beds locally appear to be vertical or dipping to the east at a high angle. The interpretation of these structures is made extremely uncertain by hillside creep and the masking of outcrops by hillwash, but their possible significance will be referred to later.

The thickness of the whole series was estimated at 1000 ft. to 1200 ft. by Howitt (1876), but the present work would suggest a total of not less than 2000 ft. and possibly rather more. The uncertainty in these figures is largely due to the difficulty of obtaining representative values for the dips of the most westerly outcrops.

A single occurrence of an interbedded flow or narrow sill was encountered on the west slopes of Mt. Tambo and could be traced for about half a mile parallel to the strike. The rock is best described as a rhyolite, containing occasional fractured and embayed phenocrysts of quartz and scattered small xenoliths of schist and quartzite in a cryptocrystalline matrix, in which the only identifiable components are abundant minute flakes of white mica. The rock shows a tendency to parallel elongation of the phenocrysts and xenoliths, suggesting flow structure, and the microlites of the matrix are aligned in two sets of planes whose acute bisectrix coincides with the direction of elongation of the larger particles (6724, 6725). The average thickness of the flow or sill is of the order of 30 ft., but no metamorphism of the sediments in contact with it could be detected.

No satisfactory palaeontological evidence for the age of this formation could be obtained. Previous records are restricted to the above-mentioned plant-beds (Selwyn 1866, Stirling 1887d, etc.). The latter mentions Sphenopteris amongst the forms present, but his specimens have not been preserved and some doubt had been thrown on the existence of these beds by subsequent workers (Gaskin 1942). The only other fossil obtained from this series was an indeterminate fish-plate collected by Broadhurst and Campbell in connection with their study of the Mt. Leinster complex.

In the course of the present investigation, plant remains were obtained at three localities, aligned practically parallel to the strike of the beds, and preserved in a very similar matrix, so that the existence of an extensive fossiliferous horizon is indicated. The most southerly of these occurrences, within five chains of the summit, is probably the one described by previous workers. At each locality, narrow stems and strap-like leaves, up to $\frac{3}{8}$ in. wide, are embedded in a matrix of yellowish or bluish micaceous shale, associated in one case with a single sporangium (?) of about $\frac{1}{4}$ in. diameter.

All these remains are unfortunately quite indeterminate, so that the age of the formation still rests on correlations based on lithology and structural features alone.

Field Relationships

At its north-eastern boundary the series rests with an angular unconformity on the schists and gneisses of the Omeo series, and a basal conglomerate is exposed on one of the spurs running into the East Branch of Tambo Gully. This contains abundant boulders and angular fragments of the schists and gneisses, up to 2 in. in diameter, and grades upwards into normal conglomerates over a thickness of some 40 ft. to 50 ft. Further south along this boundary no trace of this bed is visible, and it must be assumed that minor faulting has taken place, since the actual contact is usually sharp and well exposed, the two series outcropping within a few feet of each other.

On the west the Tambo Formation is in contact with the granite porphyry of Mt. Sisters. Stirling (1887) claimed that the porphyry intruded the sedimentary rocks, but Howitt (1876) and Whitelaw (1898) considered the sedimentary rocks were the younger. The present work supports the view that the porphyry is intrusive because it has proved the existence of a metamorphic aureole in the Tambo Formation.

Less altered rocks of the aureole occur immediately north of a prominent saddle on the main ridge, about one mile and a quarter north of the summit of Mt. Tambo. They have lost the characteristic red or purple colour of the unaltered rocks and their constituent grains are much more firmly cemented, so that they are virtually quartzites or cemented conglomerates. In thin section, however, very little evidence of recrystallization and secondary growth of the clastic particles are visible (6726-6729). Westward toward the granite porphyry these changes become more marked and the rocks approach true hornfels in appearance, assuming a blue-grey tint and greatly increasing in hardness. The actual contact with the porphyry is poorly exposed but appears to be an approximately straight line.

A number of included blocks of metamorphosed Tambo Formation, ranging in size from a few yards to ten chains, occur in the main mass of the granite porphyry. They are concentrated in a belt about a mile long and half a mile wide, running almost due west from the main contact through the low saddle between

Mt. Sisters and Mt. Pleasant. Although some of the hornfelses in this belt might have been derived from the low-grade schists outcropping to the north-west, the presence of metamorphosed conglomerates and coarse grits among them indicates that most of them belong to the Tambo Formation. The metamorphism shows no special features, the matrix of the conglomerates behaving as would a homogeneous rock of comparable texture and composition, while the larger fragments, being derived dominantly from quartz reefs and arenaceous sediments, tend to be less affected. Biotite is abundantly developed as squat, subhedral flakes in random orientation, quartz shows a tendency to the development of outgrowths in optical continuity with the primary clastic grains, and a few poikiloblastic aggregates of intimately associated small flakes of white mica and of chlorite may represent the alteration products of cordierite (6730, 6731).

Further south the boundary is a fault, unmetamorphosed members of the Tambo Formation abutting directly against granite porphyry. In the saddle of the main divide, about a mile and a half west of the summit, interbedded shales and sandstones show variable dips, ranging from 70° east through vertical to 70° west, but the strikes, which are parallel to the contact, remain uniformly at 340° to 350°. In some outcrops, though not always the ones nearest the junction, closely spaced, approximately vertical, shear-planes can be recognized, also striking parallel to the junction and giving a rough type of fracture cleavage to the rocks. The granite porphyry near the junction shows analogous shear-planes, marked by granulation, neo-crystallization, or both, occasionally with discernible movement (6840).

This junction is evidently part of a major fault which is possibly the northern continuation of the western boundary fault of the Bindi Limestones, mapped by Gaskin.

A second fault, running east-west through the previously mentioned saddle north of the summit, separates this main mass of the Tambo Formation from its metamorphosed equivalents to the north, and forms the second boundary of the fault block. The third, eastern one, is formed by the previously mentioned fault or faults north-west of the summit, which must be assumed to account for the absence of the basal conglomerate at the southern portion of that boundary.

No direct evidence as to the age of these faults is available, but they do not determine present physiography, so they must considerably pre-date the ?Pleistocene movements on the Livingstone Creek and Mountain Creek faults. They may tentatively be classed with the thrusts and faults of the Bindi district, to which a probable late Devonian or epi-Devonian age was assigned by Gaskin.

Structurally, the Tambo Formation thus comprises two distinct units in this area: the northern portion which overlies the schists and gneisses of the basement complex with an angular unconformity and is metamorphosed by the Mt. Sisters granite porphyries, and the larger southern portion which is bounded by faults on the east, north and west, but which overlies the Bindi limestones conformably at its southern extremity (Gaskin 1942).

Age

In the absence of conclusive palaeontological evidence, the age of the Tambo Formation must be established by correlation with lithologically similar beds from other parts of eastern Victoria, and by the use of its relationships to the Bindi Limestones to the south.

Gaskin, using the contact relationships at Mt. Waterson and Scrubby Creek, concluded that the Tambo Formation rested on the Middle Devonian Bindi Limestones without any marked angular unconformity and assigned an Upper Devonian or late Middle Devonian age to it. The evidence of correlation with structurally and lithologically similar occurrences in eastern Victoria tends, on the whole, to support this view, as will be shown in a later section.

The only other suggested correlation of the Tambo Formation is with the Kerri series of grits, sandstones and conglomerates in central Victoria (Thomas 1932), but since this latter series is only known to be younger than Upper Ordovician and older than epi-Devonian granodiorite, this does not throw any new light on the age of the eastern Victorian occurrences.

Wombat Creek Formation

The Wombat Creek Formation of shales, sandstones, limestones, grits and conglomerates in the extreme north of the area was examined only cursorily during the present work. It has been the subject of numerous previous reports and of several conflicting age determinations.

The beds dip much more steeply than either the Tambo Formation or the Bindi Limestones, dips of 70° to 80° being the rule and vertical dips not uncommon. As a result, their boundary against the low-grade schists to the west and south-west is based entirely on the incoming of lithologically distinctive beds, especially conglomerates and limestones, there being no apparent structural break between the two formations.

To the north the beds are overlain by 400 feet of fragmental rhyolites and silicified tuffs (Kenny 1937e), which are the southern extension of the Mt. Benambra mass described by Edwards and Easton (1937). To the south, its contact relationships are masked by the Newer Basalt flows of Frazer's Tableland and Morass Creek. Stirling (1887) recorded bosses of quartz porphyry (= granite porphyry), intrusive into these beds, and Whitelaw (unpublished) has mapped a granitic intrusion in the Mitta Mitta valley about three miles upstream of the Wombat Creek junction. The former, together with the occurrence at Gresson's Knob (see below), are closely comparable to the Mt. Sisters masses, but the latter was found to be an aplite-pegmatite-porphyritic granite complex which cannot be definitely correlated with any other igneous rock of the area.

The general structure appears to be anticlinal, with the main axis running approximately N.W.-S.E. through the vicinity of the Morass Creek-Gibbo River junction. Both the strikes and dips frequently change very abruptly and evidence of shearing is locally very marked (Whitelaw, unpublished; Kenny 1937e).

The fossils were first described by Ferguson (1899), and later in more detail by Chapman (1912, 1917, 1920). The former suggested an Upper Silurian age for the whole series, while Chapman referred a number of localities to the Middle Devonian and the remainder to the Yeringian, then regarded as Upper Silurian. There is no field evidence for any major break within the series, and it seems likely that facies differences, rather than differences in age, are responsible for the variations in the fossil assemblages.

Limestone Creek Formation

The Limestone Creek Formation, comparable in many respects to the Wombat Creek Formation, does not occur within the area, but a brief reference must be made to it for purposes of correlation. It covers relatively large areas in Limestone

Creek, Dead Horse Creek, Native Dog Creek, Stony Creek and Cowombat Creek, all situated from 15 to 30 miles east and north-east of Benambra township, but the various occurrences have not been correlated in detail. Chapman (1920) again refers some of them to the Middle Devonian and others to the Yeringian, but probably with no more justification than in the case of the Wombat Creek series.

Relationships are complicated by the fact that some members of the formation rest on volcanic and pyroclastic rocks, probably of the Snowy River Series, while others are overlain or intruded by apparently identical types. In the past, this has been explained by postulating two groups of limestones (Whitelaw, unpublished), but in the light of relationships at Bindi and Mt. Tambo it appears more probable that the sediments belong to one series only, and that the younger group of igneous rocks is to be correlated with the granite porphyries of Mt. Sisters, etc.

Trachyte-Syenite Complexes

Trachytes and syenites occur at several localities in the eastern part of the area, notably Mt. Brothers, McFarlane's Lookout, Pendergast's Lookout and Mt. Little Tambo, and at Frenchman's Hill near Omeo. They usually form prominent peaks or groups of peaks in which jointing is largely responsible in determining the slope, which is roughly constant for any particular mass. At Mt. Brothers, for example, a major set of joints striking approximately N.W.-S.E. and dipping steeply to the north-east, has given rise to extensive cliffs facing the junction of Morass and Benambra Creeks. The 700-ft. cliff of McFarlane's Lookout has been similarly caused.

They are grouped together because of petrological and structural similarities and form part of a series of alkaline intrusives, lavas and pyroclastic rocks, of which the full extent is unknown. Including Mt. Leinster, mapped by Broadhurst and Campbell (1932), where this distinctive suite was first recognized, these rocks outcrop over a total area of at least 40 square miles, the occurrences being distributed over an area of approximately 20 miles by 15 miles, and there is every possibility of other occurrences being discovered in the upper reaches of the Buchan River to the east of the area under discussion, and in the headwaters of Beloka Creek and the Gibbo River to the north-east. In addition, since the plutonic and hypabyssal phases of this suite are connected by transitional types with corresponding rocks of the granite porphyry group, the area occupied by these rocks would be increased considerably if these transition types, which are here grouped with the granite porphyries, were also taken into consideration.

Trachytes

The trachytes associated with these complexes show considerable diversity of texture, but a relatively constant mineral association. However, since they invariably preceded the plutonic phases, they have frequently undergone secondary changes due to metamorphism by the latter.

Specimens from the Mt. Leinster complex revealed no new features beyond those observed by Broadhurst and Campbell. Both flows and pyroclastics are present, but most of the specimens examined belong to the former group. They are dominantly fine-grained porphyritic types, containing variable numbers of phenocrysts of orthoclase, anorthoclase, or both, up to 2 mm. in diameter, although occasional crystals may reach 5 mm. Pale green augite, aegirine-augite, brownish-

green hornblende and deep brown biotite are the characteristic ferromagnesian minerals, having crystallized in that order (6761, 6762). The matrix consists essentially of the same minerals, with the addition of quartz as relatively large, irregular blebs in one specimen (6763). The texture is typically trachytic, although flow structures are only rarely discernible in the hand-specimen. Granular texture is less common (6763, 6764). The effects of contact metamorphism were not studied in detail in this complex, but the precipitation of finely divided iron ores within the original ferromagnesians, as described by Broadhurst and Campbell, is readily observed (6765).

Specimens from Morass Creek, north-west of McFarlane's Lookout, and from Pyroclastic Hill, east of the Marengo Gap, are closely comparable to the above described types.

Pyle's Deposit is an impure replacement limestone situated on the south-west slopes of Mt. Brothers and may conveniently by used as a locality name for a small group of trachytic rocks in which it occurs. Most specimens of these conform closely to the types already described from Mt. Leinster (6766, 6768), but minerals indicative of excess alkalies, such as aegirine-augite, are typically absent, their place being taken by an increased proportion of biotite. Pyroclastics are relatively less abundant, but occasionally examples do occur (6769). A probable dyke rock is represented by a relatively coarse-grained specimen (6770) in which the original ferromagnesians have been largely replaced by fine-grained aggregates of epidote, and in which numerous radial aggregates of alkali felspar have been developed, the individual components of the latter being laths up to 1 mm. long and ·1 mm. wide.

A rock from the same locality, but represented only by a group of boulders in the gully just north of the limestone outcrop, differs from the previously described types in that oligoclase, Ab_{75}, predominates over alkali felspar among the phenocrysts, which tend to be grouped into small clots, giving a glomero-porphyritic texture (6771). Colourless augite rimmed by biotite, subordinate green hornblende and abundant euhedral biotite, originally deep brown, now partially bleached and crowded with minute granules of iron ore, also occur as phenocrysts, all up to 1·5 mm. in diameter. The matrix is markedly trachytic, with alkali felspar predominant.

In addition to the normal contact phenomena, a number of rocks from this locality show various stages of pneumatolytic alteration and replacement. The rocks concerned were originally fragmental trachytes and ash beds, situated about half a mile from the nearest syenite outcrop. Two beds in particular have been affected. One strikes 125°, dipping 70° N.E., while the other, approximately half a chain to the south, strikes 115° and is vertical. The replacement of these beds has given rise to what is locally called Pyle's limestone deposit, first recorded by Whitelaw (1913, unpublished) but described by him as a limestone interbedded with the low-grade schists and overlain unconformably by the trachytes. This is the only locality in the area where dips and strikes can be measured on any members of the trachyte series, and the values obtained suggest that the series has undergone intense deformation and is structurally complex. It is also of interest that these strikes are almost at right angles to those of the nearest occurrences of schist, but with the limited data available the interpretation of the structure cannot be attempted.

One of the replaced beds was originally a medium-grained, porphyritic trachyte, containing phenocrysts of alkali felspar up to 3 mm. long and micro-phenocrysts of euhedral deep-brown biotite, up to 1 mm. in diameter, in a granular matrix of alkali felspar (6772). Small clots of magnetite crystals and euhedral apatites, both

up to ·5 mm. in diameter, are scattered through the rock and appear to be primary. This trachyte passes locally into a rock composed essentially of fragments, ranging in size from about ½ in. down, which consist of siliceous or trachytic material or of the fragments of larger crystals, including quartz, felspar and biotite (6774). The other bed was very much finer-grained, probably an ash-bed, and shows closely-spaced bands, somewhat contorted, which appear to be a primary feature (6773).

Alteration in the coarser-grained bed is restricted to the local replacement of felspar and ferromagnesian minerals by quartz-calcite-clinozoisite aggregates and by magnetite-chlorite-clinozoisite aggregates respectively, and to the introduction of minor amounts of pyrite, galena and chalcopyrite. In the other bed, replacement is more nearly complete, resulting in a rock composed essentially of finely granular calcite and clinozoisite, again with minor amounts of sulphides. The banding is due to variations in the proportions and grain-size of the two major constituents, and the bed contains occasional pockets and lenticles composed almost entirely of coarsely crystalline calcite with an average grain-size of about 1 mm., occasional individuals growing to as much as 1 cm. The larger of these pockets were formerly quarried and burnt for lime, but no work has been done in this locality for a number of years and the extent of the deposit appears to be strictly limited.

The central portion of Mt. Brothers is also composed of rocks which may be correlated with the occurrences described above, consisting essentially of medium-grained, only slightly porphyritic types which in many respects are intermediate between the true trachytes and the syenites. These rocks are regarded as the hypabyssal representatives of the suite, and it is probable that detailed mapping would reveal a number of distinct minor intrusions. They occupy the relatively low-lying area between the north and south peaks of Mt. Brothers and are readily distinguished in the field by their tendency to weather into relatively small angular blocks, as opposed to the larger, well rounded tors of the syenite.

At Mt. Little Tambo is the largest single occurrence of trachytic rocks. It has been referred to as granite by Stirling (1887d), but is not shown on the sketch-map of Hinnomunjie Parish by Whitelaw. Only relatively small outcrops of syenite are exposed at this locality, but the trachytes have undergone metamorphism comparable to that of the other complexes, and it seems probable that the plutonic phase underlies the whole occurrence at no great depth.

The rocks are typically strongly porphyritic types, containing phenocrysts of both orthoclase and andesine, the latter varying from Ab_{65} to Ab_{55}. The matrix may be relatively coarse-grained and rich in quartz, in which case biotite is the dominant ferromagnesian (6775), or finer-grained and almost entirely felspathic. In the latter case the ferromagnesians are purplish augite with subordinate greenish hornblende and brown biotite among the phenocrysts and aegirine-augite and biotite in the matrix (6776, 6777). One of these specimens (6776) is crowded with cognate fragments, while the other is homogeneous. In both rocks, changes in the physical environment are indicated by the presence of rounded magnetite granules rimmed by small biotite flakes in radial arrangement, and of rounded and embayed plagioclase phenocrysts, veined and penetrated by material of the matrix. The primary origin of these structures is suggested by the absence of recrystallization in other minerals of the rock, such as would be expected if contact metamorphism had been responsible for these reactions.

The Frenchman's Hill complex is the smallest in the area, but shows practically all the features observed in the other occurrences and contains a great variety of rock types. Fragmented rocks are very abundant (6778-6780, etc.), ranging from

normal agglomerates to flows crowded with xenoliths. The majority of the fragments are trachytic and can be distinguished only by differences in texture and/or grain-size, but arenaceous types are not uncommon and occasional ones correspond to rocks originally rich in ferromagnesian minerals. The last-named type are always recrystallized with the formation of granules of iron ore, small euhedral flakes of brown biotite and/or even smaller squat prisms of green hornblende. It is usually impossible to determine whether this is due to reaction with the trachyte matrix or to subsequent metamorphism by the syenite, since the matrix does not show any evidence of recrystallization until a fairly advanced stage of metamorphism is reached.

Among the massive rocks, it is not usually possible to distinguish extrusive from intrusive types, but the field relations of some of the phases at the western and north-western extremities of the complex suggest that dykes and small bosses were locally important and may exceed the extrusive phases in extent over small areas. Porphyritic types, with phenocrysts of slightly perthitic orthoclase, up to 2 mm. long, predominate, and the matrix may be trachytic (6781), or granular (6782), and may contain minor amounts of interstitial quartz (6783). Magnetite is usually the only primary ferromagnesian mineral present, although the occurrence of abundant irregular aggregates of minute epidote granules indicates that one or more other dark minerals were originally present in some of the specimens (6784, etc.).

With an increase in alkali contents, these rocks pass into the types described as solvsbergites by Skeats (1912) and later workers. They are characterized by the presence of aegirine, pleochroic deep green to yellowish green, and riebeckite, pleochroic deep blue to greenish blue (6785-6787). These minerals occur only as interstitial grains or strongly poikilitic crystals, and are never very abundant. The matrix is always granular and very rich in an untwinned alkali felspar (?orthoclase), characterized by the presence of very well developed striations, due to the presence of very fine lamellae of slightly different refractive index, probably albite, which are always arranged parallel to an extinction direction of the crystal. Quartz is always present, although in small amount. Magnetite and rare biotite are the only other dark minerals, and sphene is the most abundant accessory.

The metamorphosed equivalents of all these types can be recognized in various stages of alteration. The breaking down of the ferromagnesian minerals, especially biotite, with the precipitation of numerous minute granules of iron ore, occurs at an early stage (6788). This is followed by the development of small irregular flakes of brown biotite and subhedral crystals or squat prisms of green hornblende scattered through the rock, probably by a redistribution of material from original xenoliths rich in dark minerals (6789, 6790). Fluorite is occasionally present in small amount, both in the matrix and in association with arenaceous xenoliths. The matrix also shows evidence of recrystallization, areas of clear, slightly coarser-grained felspar replacing portions of the originally finely granular aggregates of cloudy ?orthoclase. The striations are, if anything, even more marked in the recrystallized material than in the original matrix (6790, etc.). At the same time, the phenocrysts tend to extend by forming outgrowths in optical continuity with the original crystals (6791), which may give rise to a marginal zone crowded with inclusions of material from the matrix. Quartz is also redistributed and possibly introduced in part from the syenite, giving rise to pools, up to 2 mm. in diameter, in which any of the other minerals of the rock may be enclosed (6791).

Smaller masses of trachytic rocks also occur at Mt. Bung Bung, south-east of Benambra township, at Morass Creek, north-west of McFarlane's Lookout and at scattered other localities, but these occurrences show no features of special petrological or structural interest.

Syenites

Syenitic rocks form part of every one of the previously listed trachyte-syenite complexes, and they are grouped together because of similarities in mineral contents and mode of occurrence. The most easterly masses, except for Mt. Leinster itself, are those of McFarlane's Lookout and Pendergast's Lookout, about ten miles north-east of Benambra township, which were mapped by Broadhurst and Campbell as part of the Mt. Leinster complex. About four miles north of Benambra another mass occupies an area of about 15 square miles, forming the northern and southern peaks of Mt. Brothers, and small outcrops are also associated with the complexes centred on Mt. Bung Bung and Mt. Little Tambo.

In the central portion of the area, the only occurrence of rocks of this group is the isolated, much smaller mass which forms the core of the Frenchman's Hill complex, about two miles north of Omeo.

Heavy mineral analyses of the syenites, as well as of the granite porphyries and granites to be described later, appear in Table 1. Rosiwal analyses appear in Table 3.

A rapid re-examination of the most easterly complexes gave results in general agreement with those of Broadhurst and Campbell. The rocks are pale grey in the hand-specimen, weathering reddish, and are not markedly porphyritic. Perthitic orthoclase makes up the bulk of the rocks, occurring as crystals up to 4 mm. in length, always anhedral, either sub-rounded as in a specimen from Mt. Leinster (6793) or interlocking as in a rock from McFarlane's Lookout (6792). The amount of quartz varies from a trace (6792) to that of a major constituent. Its habit is always interstitial, but occasionally it forms coarse micrographic intergrowths with alkali felspar, as in a rock from the west bank of Morass Creek opposite Pendergast's Lookout (6794). The ferromagnesian minerals, as pointed out by Broadhurst and Campbell, are extremely variable. Magnetite, pale green augite, aegirine-augite, green hornblende and strongly pleochroic brown-black biotite are present in most specimens, having crystallized in that order, since any of them may be surrounded by any of the later-named ones. The crystals are typically subhedral, ranging up to 2 mm. in diameter, and are usually enclosed by the alkali felspars. In addition, one specimen (6793) shows purple, non-pleochroic augite side by side with the greenish variety, both being sometimes rimmed by aegirine-augite. Broadhurst and Campbell also record bluish hornblende in one rock (2618), which appears to be riebeckite.

Broadhurst and Campbell referred to these rocks as pulaskites and nordmarkites, according to the amount of quartz present. The type pulaskite from Arkansas, however, contains nepheline both in the mode and in the norm, whereas the rocks of the Mt. Leinster complex are never quite free from quartz. The name is thus not appropriate and the rocks are best referred to simply as soda-syenites and quartz syenites.

The Mt. Brothers mass is rather more variable in texture and mineral composition, ranging from soda-syenite to soda-granite, and including both porphyritic and even-grained varieties. The south-eastern and north-eastern portions of the mass, including all the main peaks, are strongly porphyritic, containing sub-

rectangular phenocrysts of alkali felspar, up to 2 in. in length, and have been described as a porphyritic granite (Whitelaw, 1898). The phenocrysts are orthoclase, which is locally faintly perthitic or encloses scattered blebs of plagioclase in optical continuity with each other. In the hand-specimen, they show marked schiller on the (100) faces, identified by the acute bisectrix figure obtained from sections cut parallel to this plane. This also coincides with a rough parting and a slight elongation of the crystals to give an approximately tabular form.

Plagioclase also occurs independently as subhedral, zoned crystals up to 5 mm. long, ranging from oligoclase, Ab_{75} (6798), to andesine, Ab_{65} (6796), although some of the material exsolved from the perthites may be more sodic. It is always subordinate to the alkali felspar, but the difference is not very considerable, so that some of the rocks may be referred to as monzonites and adamellites. Quartz is always present, either as irregular grains, forming part of the matrix, or in micrographic intergrowths with some of the smaller alkali felspars and with the marginal portions of the phenocrysts. Magnetite, greenish brown hornblende and deep brown or greenish brown biotite are the only ferromagnesian minerals present, occurring in much the same way as in the Mt. Leinster rocks. Sub-rounded apatite and euhedral zircon and sphene are important accessories, usually closely associated with small clots of the ferromagnesian minerals.

An interesting specimen is provided by a partiallly assimilated xenolith of trachyte near the south-western border of the mass (6799). The xenolith has been reconstituted so as to contain a mineral assemblage similar to that of the syenite itself, with the addition of purplish augite which forms rounded grains, rimmed by aegirine-augite or by hornblende. The average grain-size of this specimen is only about 2 mm. and phenocrysts are absent, the alkali felspar forming a mosaic of interlocking grains which frequently enclose some of the smaller crystals of the dark minerals. Quartz is present in traces only, but apatite is relatively abundant, forming numerous slender needles enclosed by the felspar.

Along the west and north-western borders of the mass the rocks are more closely comparable to those of McFarlane's Lookout and Mt. Leinster. No phenocrysts of alkali felspar occur, and quartz is less abundant (6800). At these points, exposures are not sufficient to show the contact relationships between the main mass and the non-porphyritic types, but occasional sharply defined pockets of the coarser-grained phase, up to a few chains in diameter, occurring within the finer-grained rocks, suggest that the former is the younger of the two. This is confirmed by relationships north-east of the main peak, where a tongue of the porphyritic variety crosses Morass Creek and comes into contact with the finer-grained rocks of McFarlane's Lookout. Near the contact, the phenocrysts become less abundant and are concentrated into small clots. At the same time, veins and lenticles of fine-grained aplite and occasional ones of graphic granite appear, cutting both rock types indiscriminately. No sharp boundary can be traced, but the relationships suggest that the porphyritic phase is the younger, being possibly intruded before the complete consolidation of the even-grained phase, so that some intermingling of the magmas took place.

This interpretation is in agreement with the observations of Broadhurst and Campbell, who described scattered pockets of coarser-grained rocks, believed to represent late phases, interspersed with the even-grained rocks of McFarlane's Lookout. The differences between the two types, including the greater abundance of quartz and of acid plagioclase, and the absence of pyroxenes in the porphyritic

phase, can all be accounted for if the latter is regarded as the product of consolidation of a residual magma, relatively enriched in silica, soda and mineralizers.

At Mt. Bung Bung and Mt. Little Tambo syenites comparable to both the even-grained and the porphyritic varieties of Mt. Brothers occur, but the total area covered by these masses is only of the order of three to four square miles. The rocks do not differ in any essential way from their above-described counterparts, but purplish augite and epidote are present in the porphyritic phase (6859), which is rather poorer in quartz than the corresponding rock from Mt. Brothers, and the even-grained phase tends to be rather richer in dark minerals, including magnetite, greenish-brown hornblende and deep brown biotite than corresponding rocks from elsewhere in the area (6802, 6829).

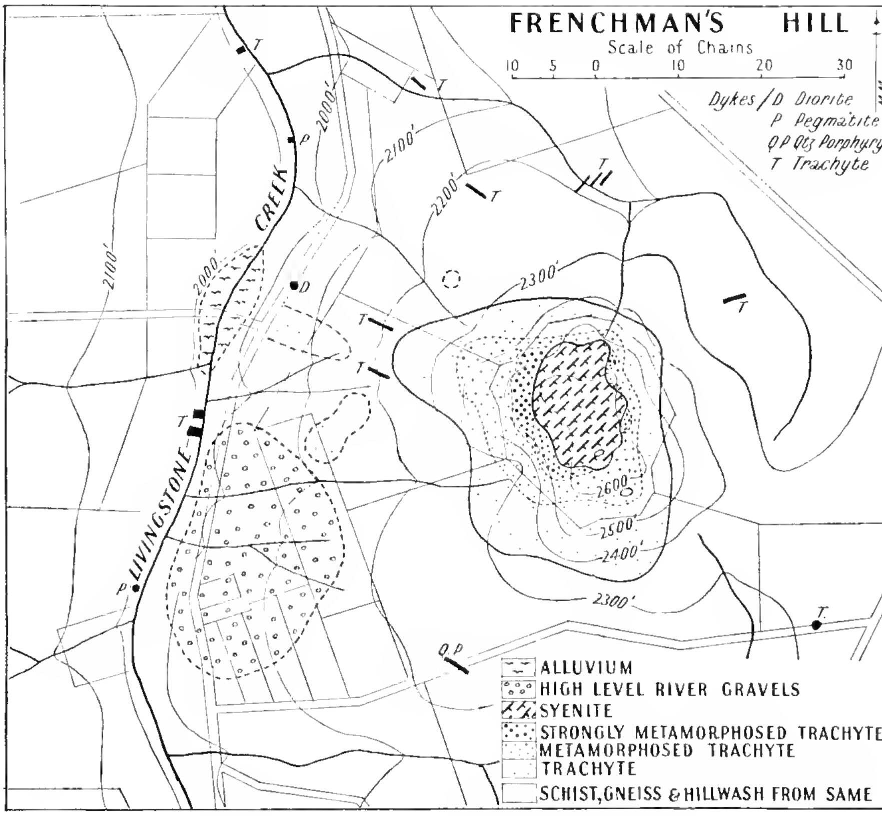


FIG. 4.—Geological Map of Frenchman's Hill.

One very distinctive type (6803) differs from all other comparable specimens in showing a strong tendency for the orthoclase felspars to develop an interlocking texture and to enclose numerous small blebs of a component of slightly higher refractive index but of the same birefringence and extinction of the host (albite ?). The ferromagnesian minerals of this rock are essentially greenish-brown hornblende and occasional granules of iron ore, both of which may be rimmed or partly replaced by small elongated flakes of biotite. No quartz appears to be present.

The only other occurrence of syenitic rocks within the area is that of Frenchman's Hill, occupying an area of only about 200 yards by 200 yards (6804, 6805).

The mass was first described by Howitt (1890), who referred to these rocks as orthoclase porphyries and compared them to similar types from Mt. Leinster. Skeats (1912) referred to them as solvsbergites 'approaching a plutonic habit,' and implied a gradation from them into the surrounding trachytes, which, however, has not been confirmed by the present observations.

The rocks consist dominantly of subhedral crystals of orthoclase, up to 5 mm. in diameter, enclosing occasional blebs of sodic oligoclase, Ab_{85}, or albite, Ab_{90}, in parallel orientation. Quartz forms smaller, subhedral grains and also occurs in micrographic intergrowth with the alkali felspar to form the matrix of the rock. The felspar of these intergrowths is frequently in optical continuity with one of the adjacent larger crystals, but the preservation of the crysal form of the latter shows that the crystallization of the matrix was separated from that of the phenocrysts by a definite interval of time. Biotite and iron ore are the only ferromagnesian minerals occurring in the rock, the former as clots of small euhedral flakes, the latter as relatively abundant and relatively coarse grains of original ?haematite, now largely altered to limonite, up to 2 mm. in diameter, typically moulded on the larger crystals of both quartz and felspar.

Occasional sedimentary xenoliths occur within this mass, consisting essentially of granular quartz, only slightly recrystallized, and of scattered biotite, which has been more thoroughly reconstituted (6807). No transfer of material from the igneous rock appears to have taken place.

Contact Rocks

The contact relationships of the different masses are very similar. In each case, the plutonic phase is preceded by flows, dykes and agglomerates of trachytic rocks, into which it is intrusive and which it has contact metamorphosed. The Frenchman's Hill mass is completely surrounded by these trachytes and does not come into contact with schists or gneisses, but at Mt. Brothers and McFarlane's Lookout the syenites have intruded the low-grade schists and have altered them to blue-grey or blue-black hornfelses for distances of five to ten chains from the contact.

In the less altered rocks, recrystallization is restricted to the reconstitution of white mica into irregular aggregates of small sub-parallel flakes (6808) and the development of poorly defined spots of incipient cordierite, up to 1 mm. in diameter (6809). In rocks nearer the contact, biotite is developed as abundant small euhedral deep-brown flakes (6810), and is accompanied by large irregular patches of strongly poikilitic cordierite, developed from the spots of the lower-grade rocks (6811, 6812). These rocks may show parellelism of the newly formed biotite flakes and parallel elongation of the cordierite poikiloblasts, or of the original quartz grains, but no banding or foliation is ever apparent in the hand-specimen.

A contact between syenite and granodiorite has been described by Broadhurst and Campbell from Mt. Leinster, but none of the syenites in the area of the present investigation comes into contact with the granodiorites or their gneissic equivalents.

Thickness of Cover

The question of the cover of these syenites presents an interesting problem, since they now rise to approximately 2000 ft. above the level of their associated flows and pyroclastics, as at Pyle's deposit on the west flank of Mt. Brothers. Assuming a cover of only 1000 ft.. for the Mt. Brothers mass and original relief of the order of 1000 ft., this still presupposes an original thickness of 2000 ft. for

the trachyte series over an area of the order of 80 to 100 square miles. The volume of lava involved is therefore comparable to that met with in the dacite suites of central Victoria, but the available evidence does not justify any conclusions as to the mechanics of its extrusion.

Associated Dykes

The number of dykes to be definitely correlated with the trachyte-syenite complexes is comparatively small and only a limited range of petrological types is represented.

Aplites are best represented in and near the northern and eastern parts of the Mt. Brothers mass, especially in the vicinity of the contact between the porphyritic granite and the even-grained syenite of McFarlane's Lookout. They are normal aplites, rich in quartz and perthitic orthoclase, and contain biotite as their main ferromagnesian constituent (6813).

Normal trachytic dykes are most abundant in the immediate vicinity of Omeo, where they show a general tendency to be arranged radially with respect to Frenchman's Hill. Flow structure is usually visible in the hand-specimens, as well as in thin section (6814, 6815, etc.), and is due to the local parallelism of the felspar laths of the matrix. Quartz is usually present in small amounts only, occurring as scattered interstitial grains or as pools enclosing the felspar laths of the matrix. Phenocrysts of alkali felspar are occasionally present (6818), but do not greatly affect the texture of the rock as a whole. Abundant magnetite, ranging from minute scattered needles to clusters of relatively large crystals, is always present, typically altering to limonite, which is responsible for the characteristic pink or pale brown colour of these rocks. It is occasionally accompanied by remnants of chloritized biotite (6814, 6818), which, however, always remains subordinate in amount.

One compound dyke from Wilson's Creek is exceptional in containing numerous xenoliths of sedimentary origin, mainly quartz-rich schists, up to 2 in. across. Those portions of the dyke richest in xenoliths (6819, 6820) are characterized by fine grain-size and by the abundance of relatively large brown biotite flakes, which may, however, have been derived from the xenoliths. This contrasts with the texture of the remainder of the dyke (6821), which is coarser-grained, slightly porphyritic and poor in dark minerals other than magnetite.

A dyke from the north shoulder of Mt. Livingstone is of interest in showing evidence of shearing, suggesting that movements at that locality, which falls within the Dry Creek - Three-Mile Creek shear zone, persisted rather longer than elsewhere in the area. The rock is traversed by irregularly spaced, sub-parallel shear planes, intersecting the flow-structure at a low angle, along which concentration of limonite has taken place.

In the eastern part of the area, trachytic dykes are less numerous, although Broadhurst and Campbell have recorded a variety of types from Mt. Leinster. Apart from the aplites of the Mt. Brothers mass, only two dykes associated with the alkaline complexes were found in this part. One specimen (6822), from the Main Divide, east of Marengo Gap Hill, is a quartz-rich, trachytic type with poorly developed flow structure and containing relatively abundant magnetite and biotite in various stages of alteration. The other (6823), from east of Mt. Bung Bung, is a more basic rock, not unlike some of the lamprophyres in appearance, but distinguished by the presence of sub-rectangular phenocrysts of simply twinned orthoclase, up to 1 mm. long. The original ferromagnesian minerals, both among

the phenocrysts and in the matrix, have been completely replaced by chlorite-epidote aggregates, and are no longer identifiable. Before alteration, the rock may have had the mineral composition of a vogesite, but no comparable unaltered rocks have been found in the area.

Granite Porphyries

The granite porphyries of the area occur as a number of small stocks, especially in the southern portion of Frazer's Tableland and in the hills north of Mt. Brothers, and as a few rather larger complexes, of which Mt. Sisters, Mt. Pleasant, Mt. Bung Bung and Marengo Gap Hill are the most important. The total extent of these rocks within the area is of the order of 30 square miles, but very much larger occurrences are known from adjacent districts and will be referred to subsequently.

The stocks of Frazer's Tableland have been recorded by Stirling (1887e) and the complexes of the Mt. Sisters-Mt. Pleasant area by H. S. Whitelaw (1898). In addition, Broadhurst and Campbell (1932) mapped the Marengo Gap Hill occurrence in detail and showed it to be younger than the granodiorites of the gneissic series.

The rocks vary widely in texture, but maintain a relatively constant mineral association, variations within any one complex being comparable to those between representative rocks from different complexes.

At Mt. Sisters, the dominant type is a quartz-felspar porphyry containing sub-rectangular crystals of perthitic orthoclase, which tend to be grouped into small clots of eight or ten individuals, and embayed and rounded crystals of quartz, both up to 3 mm. in diameter, in a matrix composed essentially of the same minerals in micrographic intergrowth. Both constituents of these intergrowths tend to be in optical continuity with nearby phenocrysts, but the oultines of the latter are always sharply defined, showing that their crystallization was complete before that of the matrix began. Ferromagnesian minerals are represented by scattered small flakes of biotite, typically in an advanced stage of chloritization, and in one specimen (6827) by clots of small euhedral biotites and magnetites which may represent xenolithic material in various stages of assimilation. Fluorite is an important accessory in one rock (6828), where it forms scattered grains, ·3 to ·4 mm. in diameter, which have crystallized after felspar but before quartz.

A minor but very widely distributed type shows many of the features characteristic of some of the syenites, and may be regarded as transitional between the typical rocks of the two series. One specimen (6830) consists largely of irregular to sub-rectangular crystals of strongly perthitic untwinned alkali felspar (orthoclase ?), up to 2 mm. long, the enclosed member being acid oligoclase, Ab_{85}. The matrix is subordinate in amount and consists of smaller crystals of the same mineral, enclosed in irregular grains and small pools of quartz. Both biotite and amphibole are present, the former usually strongly chloritized, the latter pleochroic greenish brown to pale yellowish green, or deep bluish green to pale yellowish green (riebeckite ?). Another member of the same group (6831) shows again the very high contents of perthitic alkali felspar, characterized this time by a very pronounced arrangement of the inclusions in parallel or sub-parallel laminae. It differs, however, in the almost complete lack of dark minerals, and in the texture. Both quartz and felspar show a continuous gradation from micro-phenocrysts of about 1 mm. diameter down to the matrix of average grain-size ·1 mm. approximately. No graphic intergrowths are present, and the quartz occurs throughout as rounded, equidimensional granules, although adjacent grains may occasionally be

in optical continuity. The felspar, on the other hand, tends to be poikilitic towards quartz, and commonly encloses blebs and granules of the latter, either throughout the crystals or in the marginal portions only.

A chilled border phase, about two to three chains wide, can be recognized along the northern edge of the mass, and is distinguished in the hand-specimen by its darker colour and finer grain-size (6832). Essentially, it differs from the main mass by the absence of quartz phenocrysts and the absence of graphic intergrowths in the matrix. The dominant ferromagnesian mineral is a deep-green hornblende with an extinction angle of 18°, occurring as abundant small prisms and irregular crystals, magnetite being subordinate, and biotite absent altogether.

Rocks from the Mt. Pleasant and Mt. Bung Bung complexes are essentially similar, ranging from true granite porphyries to transition phases between these and the syenites. Quartz may be abundant, especially in the former type, and the phenocrysts then show the bi-pyramidal habit characteristic of these rocks from all occurrences (6833, etc.).

Rocks from the Marengo Gap Hill occurrence show considerable variation, and contain representatives of most of the types already described. The dominant phases at this locality, however, tend to be more sodic in their affinities, a considerable proportion of acid plagioclase being always present. Strongly porphyritic rocks predominate, especially in the northern portion of the complex, and contain phenocrysts of somewhat embayed quartz, sub-rectangular perthitic orthoclase, and subhedral oligoclase, Ab_{85}, all up to 5 mm. in diameter, in a finely granular quartz-felspar matrix. Plagioclase may be subordinate to orthoclase among the phenocrysts (6825, 6826), or may almost equal it in amount, but since the ground-mass felspar is dominantly orthoclase, the rocks still fall into the group of granite porphyries. Green-brown biotite in various stages of chloritization is the dominant ferromagnesian mineral, with magnetite subordinate. Fluorite again occurs as an accessory in some specimens.

For the less obviously porphyritic types, in which plagioclase is typically present in small amounts only, a specimen from the southern portion of the mass may be regarded as typical (6834). These are in every way comparable to the corresponding rocks from Mt. Sisters, etc., and require no detailed description.

The relatively small masses of Frazer's Tableland and the Mitta Mitta valley in the vicinity of Four-Mile Creek and Eight-Mile Creek are closely comparable with some of the rocks previously described, but each mass is homogeneous, consisting of one type only. The occurrence at Gresson's Knob, about six miles north-north-west of Benambra, is typical of the group. The outcrop occupies an area of about half a mile by half a mile, and consists of a markedly porphyritic rock, containing phenocrysts of originally bi-pyramidal clear quartz, now rounded and embayed, and of pink or flesh-coloured subhedral albite, Ab_{95}, both up to 5 mm. in diameter. Strongly sericitized alkali felspar and bleached or chloritized biotite form smaller and less numerous phenocrysts, while the pale yellow matrix consists essentially of finely granular quartz and unidentified felspar (6837).

The masses of Sloan's Knob, east of Morass Creek, consist of petrologically similar types, but their field relations are masked by flows of Newer Basalt, which overlie them to the west, and their eastward extent was not investigated. Similar masses also outcrop in the Mitta Mitta valley, opposite the mouth of Four-Mile Creek, with the addition of a less acid type with a coarser-grained matrix. In this rock, biotite as well as quartz and felspar forms phenocrysts, and a gradation exists between these and the crystals of the matrix.

Field Relationships

The relationships of the various types within any one complex to one another are not readily discernible. At Mt. Sisters there is a suggestion that the more porphyritic and more quartz-rich phases transgress the boundaries of the more nearly equigranular and more felspathic types, and are therefore younger than these. No actual contacts, however, were exposed. At Mt. Bung Bung and Marengo Gap Hill the various phases alternate irregularly and do not appear to be connected by transition types, but again no actual contacts were seen.

The intrusive nature of the Mt. Sisters mass is evident from the contact metamorphism which the low-grade schists, and also the Tambo Formation as already described, have undergone at its boundaries. Similar alteration on a smaller scale can be detected also at the borders of the other, smaller masses. Even at Mt. Sisters, high-grade metamorphism is restricted to a zone within a chain of the contact, but the effects are very well shown by some inliers of sedimentary rocks in the vicinity of the low saddle between Mt. Pleasant and the Main Divide. The products here are relatively fine-grained blue-black hornfelses, containing abundant small biotites in random orientation, and occasional spots of incipient cordierite, poikiloblastic towards both quartz and biotite (6835).

A small occurrence of granite porphyry at Mt. Little Tambo is important because it gives an indication of the relationship between the granite porphyries and the trachyte-syenite complexes. The rock is pale grey, markedly porphyritic, and rather finer-grained than most members of this group, occurring as an isolated outcrop of two to three chains diameter, completely surrounded by trachytic rocks. The exact boundaries of this occurrence are masked by hillwash and vegetation, but appearances strongly suggest that it is intrusive into the trachytes. If it is regarded as contemporaneous with the larger masses such as Mt. Sisters, and there is no reason why this should not be done, these masses are likewise post-trachytic.

Alteration

Hydrothermal alteration of these masses is not uncommon, and can be best observed at the south-west extremity of the Marengo Gap Hill occurrence and in the eastern part of the outcrop at Gresson's Knob. In the hand-specimen the altered rocks rather resemble leached outcrops, but no sulphides are present and the alteration can be seen to consist essentially of the replacement of original felspar by relatively coarse aggregates of white mica, and of original biotite by white mica and chlorite (6838, 6839), together with a certain amount of silicification. The altered portions pass into the main unaltered masses within a relatively short distance and the changes must be ascribed to the action of vapours or solutions derived from the intrusions themselves. There is a close analogy between these processes and those which caused the alteration of some of the dyke rocks associated with the Red Granite, to be described later.

Red Granite

The Red Granite is the largest single intrusion in the area, occupying an area of approximately twelve miles by six miles, between Glen Wills and Hinnomunjie Bridge, with its maximum diameter N.E.-S.W., approximately at right angles to the trend of the country rock structures. It is well exposed over most of this area and typically develops numerous large tors.

It occupies the central portion of the area enclosed by the great southerly bend of the Mitta Mitta, but does not appear to have had a major effect on the develop-

ment of the topography. The Big River, Bundarra River and Cobungra River all cut across its contact near the Blue Duck Hotel, as does the Mitta Mitta near the mouth of Nine-Mile Creek, and in no case except that of the Bundarra is there any noticeable change in the valley cross-section. The steepening of the Bundarra valley, however, is due to rejuvenation by the Livingstone Fault, and the coincidence of the knick point with the granite boundary is purely coincidental.

The mass is comparable to the Red Granites of Pine Mt. and Mt. Mittamatite described by Edwards and Easton (1937), differing only in its somewhat greater extent and in the presence within it, especially near the southern and south-eastern borders, of very numerous veins, dykes and lenticles of aplite, pegmatite and quartz porphyry. Of these dyke rocks, only the quartz porphyries extend into the country rock for any considerable distance and no attempt has been made to map the very numerous smaller masses, which locally equal the main mass in abundance over areas up to half a mile across. A smaller number of intermediate and basic dykes are also associated with the mass, and occasionally cut it. They will be discussed in detail in a later section.

Petrology

The mass itself is reasonably homogeneous, the typical rock (6733, 6735) consisting essentially of quartz and perthitic orthoclase in about equal amounts, occasionally tending to form a very coarse type of micrographic intergrowth, together with slightly less abundant oligoclase, Ab_{70}. Rarer biotite, pleochroic yellow to deep brownish green, occasionally bleached, and scattered magnetite are the only other constituents present in significant amount. The rock is approximately equigranular, with an average grain-size varying between 1 and 3 mm., but may appear porphyritic in the hand-specimen, due to the tendency of the plagioclase to occur as euhedral crystals, which contrast with the irregular outlines of the other major constituents. The red colour is apparently due to the presence of finely divided haematite in the alkali felspar.

Contact Phenomena

The contacts of the main mass are not usually well exposed. Where the country rocks were previously unmetamorphosed sediments, contact metamorphism has been restricted to the formation of cordierite-biotite hornfelses for a few chains from the contact, and where the rocks had previously undergone regional metamorphism the original schistosity and spotting are only partly obliterated.

Where the Red Granite is intrusive into gneisses, as on the west slopes of the Knocker and near the mouth of Nine-Mile Creek, sharp contacts do not occur. The general trend of the boundaries cuts across the foliation of the country rock, but a transition zone, from one to ten chains wide, appears to connect the two rock types. This is illustrated by a series of specimens across the contact on the western slopes of the Knocker (6736-6743). The first specimens (6736, 6742, 6743) show what is essentially a contact-metamorphosed ortho-gneiss. Anhedral quartz, perthitic orthoclase and subordinate oligoclase, Ab_{75}, all with an average grain-size of about 2 mm., together with less abundant, smaller flakes of biotite, made up the major portion of the original rock. Along the grain boundaries, and within some of the larger grains, especially of alkali felspar and of biotite, granulation and recrystallization have given rise to fine-grained aggregates of quartz, alkali felspar and biotite, the latter locally showing good parallelism, together with topaz, clino-

zoisite, muscovite and bright yellow isotropic pinite(?) in smaller amounts. The second group of specimens (6737, 6741) approximate to the normal granite, differing mainly by their paler colour, the hand-specimens being cream rather than reddish, and by their distinctly higher contents of biotite. In thin section, they show the coarse micrographic intergrowth and the deep green biotite characteristic of the Red Granite, with a strong suggestion that, in some instances at least, the orthoclase has developed at the expense of quartz. The proportion of oligoclase, Ab_{80}, is somewhat higher than in the main mass of the Red Granite and the rock may be regarded as a contaminated phase of the latter, or as the equivalent of a chilled border phase, slightly more basic than the main mass. The third group of specimens (6738, 6739, 6740) appear scarcely distinguishable from the typical Red Granite in the hand-specimen, but still contain significantly higher proportions of plagioclase and biotite than the normal rock. No specimens illustrating the actual transfer of material from the granite to the country rock were obtained, but the absence of a sharp contact strongly suggests that such a process must have taken place at least on a small scale.

Associated Dykes

In the case of the Pine Mt. and Mt. Mittamatite occurrences, the associated dyke swarms preceded the main intrusion (Edwards and Easton 1937), but the relationship is reversed in this area, since some at least of the hypabyssal rocks cut the main intrusion. These include a large number of small veins and lenticles of aplite and pegmatite, which show a marked tendency to be concentrated in a comparatively narrow belt, parallel to the boundary of the granite mass, and a smaller number of more persistent dykes of quartz felspar porphyry which extend for distances of up to six or eight miles into the country rock, especially to the south and south-east of the main mass.

Aplites and Pegmatites

A specimen from the Alpine Highway (6744) may be regarded as typical of the aplitic rocks, with orthoclase present in about equal amount to albite, Ab_{90}, and muscovite as the only ferromagnesian mineral. In a related rock from the Glen Wills Highway (6745), the orthoclase is strongly perthitic and locally passes into oligoclase-antiperthite, Ab_{85}. With an increase in the ferromagnesian constituents, mainly chloritized biotite, these rocks pass into a type which might be described as a plagioclase aplite, characterized by the presence of strongly zoned, untwinned plagioclase side by side with albite, similar to the above, and represented by rocks from the Glen Wills Highway and other localities (6746, etc.).

A somewhat larger intrusion of this type which deserves mention on account of some structural peculiarities occurs on the south-eastern slopes of Mountain Creek. This is a relatively coarse-grained aplite which forms a lenticular mass of about 300 yards by 150 yards and consists essentially of quartz, albite, Ab_{95}, slightly perthitic orthoclase and abundant muscovite, which occurs as small ragged flakes arranged in two sets of planes intersecting at 60° to 80° (6747). Scattered through the mass and aligned normal to the lineation resulting from the intersection of these two sets of planes, are abundant small veins and lenticular masses of pegmatite, consisting of irregular quartz, subhedral pink orthoclase, muscovite and tourmaline, all as individuals up to 2 cm. in diameter. The muscovite of these pegmatites is arranged predominantly normal to the walls of the veins, which grade into the

matrix in a distance of about 1 to 2 cm. Using Sander's nomenclature, these veins are regarded as occupying tension gashes lying in the *ac*-plane of deformation of the rock, while the two sets of planes outlined by the muscovite flakes are thought to represent shear planes coinciding with (*h0l*) directions. Moreover, the absence of deformation within individual grains indicates that the movements responsible for these structures occurred during a late stage of crystallization rather than after complete solidification.

Another rock from Bingo Creek is closely comparable to the above, but lacks the directional structures (6748). It differs from the majority of the members of this group by its rather coarser grain-size, 1 mm. being the average for most of the major constituents, which are quartz, slightly cloudy orthoclase and acid oligoclase, Ab_{85}, together with relatively abundant muscovite. The felspars are typically subhedral, the quartz anhedral or interstitial, with adjacent individuals occasionally coarsely intergrown, and the muscovite occurs as relatively coarse flakes, typically moulded on the felspars and occasionally coarsely intergrown with quartz.

In addition, a very distinctive group of rocks, which may be referred to as aplites or fine-grained pegmatites, occur as numerous irregular masses within the main area occupied by the Red Granite. The extent of these rocks varies from veinlets and lenticles a few feet long to masses a quarter of a mile or more in diameter, the majority occurring in the south and south-eastern portions of the mass. A typical specimen (6734) is a medium-grained even-grained granular whitish rock, consisting of embayed, originally euhedral quartz, and subhedral albite, Ab_{95}, together with less numerous but rather larger crystals of ?microcline, which occasionally shows evidence of having developed at the expense of quartz. Original biotite is represented by occasional fine-grained chlorite-sericite aggregates, and magnetite occurs as scattered small crystals. The boundaries of these masses are usually sharp but irregular and the rocks are thought to be the products of a residual phase of the Red Granite magma, relatively enriched in soda and in volatile constituents, the latter being responsible for the slight auto-pneumatolytic alteration which most of these rocks show.

Felspar Porphyries and Porphyrites

Of the felspar porphyries and porphyrites, only those occurrences which have been definitely correlated with the main Red Granite intrusion will be discussed in this section. These include especially a group of dykes from Bingo Creek, Sam's Hill and McMillan's Lookout, averaging 12 ft. to 15 ft. in width and striking dominantly N.W.-S.E., parallel to the dominant trend of the country rocks.

In the hand-specimen, they are pink or flesh-coloured rocks, studded with phenocrysts of glassy bi-pyramidal quartz, cream and red felspar and occasional greenish-black, strongly chloritized biotite and/or hornblende. The size of the phenocrysts in any one rock is approximately uniform, 1 to 2 mm. being usual (6749, 6750), but 5 to 10 mm. being occasionally found (6751). In thin section, the quartz is seen to be strongly embayed and the dominant felspar is albite, Ab_{95}, showing albite and pericline twinning and tending to occur in small clots of six to ten individuals. Slightly perthitic orthoclase is subordinate, but always present. The matrix consists essentially of quartz and an unidentified felspar, probably orthoclase, the latter locally in micrographic intergrowth with quartz or recrystallized to form spherulitic aggregates. The original ferromagnesian minerals have been almost completely replaced by chloritic aggregates and appear to have originally

included both hornblende and biotite. Muscovite is typically absent, but iron ores are present in moderate amount.

Slight shearing has affected some of these rocks (6752, 6753), resulting in traces of granulation along irregularly spaced planes and causing the rocks to break more readily in certain directions.

Contaminated Felspar Porphyries and Porphyrites

Two rocks from the Glen Wills Highway near the Bingo saddle (6754), and from the lower portion of Day's Creek (6755, 6756), deserve special attention. They are quartz-felspar porphyrites comparable with the above types, except for the texture of the matrix, which tends to be controlled by the presence of abundant uniformly small laths of unidentified felspar, quartz being less abundant and typically interstitial. The proportion of chlorite is relatively high and epidote is also present as isolated grains, as small aggregates and as rims around some of the rounded and embayed quartz phenocrysts. The most distinctive feature of these rocks, however, is the presence within them of numerous sharply defined patches, up to 2 in. in diameter, which differ from the main mass of the rocks in their higher contents of chlorite and epidote and by the absence or relative scarcity of phenocrysts. These patches, which are very prominent in the hand-specimen because of the contrast between their greenish colour and the light brown or reddish tint of the matrix, appear to be xenoliths of a more basic rock, possibly comparable with the hornblende porphyrites described in a later section. No actual contacts between the two rock types were observed, but if the more basic rocks belong to the same general period of igneous activity, as seems very probable, then the order is the reverse of that observed by Edwards and Easton in north-eastern Benambra, where the succession is from acid to basic types.

Granitic Rocks of Uncertain Age

Two rather inhomogeneous masses of granitic rocks are possibly to be correlated with the Red Granites. One occurs in the Big River valley about five miles upstream of Glen Wills. It consists of a complex of granite, granite aplite and granite porphyry (6757, 6759), all characterized by the presence of perthitic orthoclase, which forms the phenocrysts of the porphyritic types and is approximately equal in amount to plagioclase in the even-grained rocks.

The other occurrence, from the Mitta Mitta valley, comprises fine-grained granites and granite aplites which have intruded slates and sandstones of the Middle Devonian (?) Wombat Creek series. A typical specimen (6760) consists of subhedral perthitic orthoclase and subordinate oligoclase, Ab_{70}, both up to 1 mm. in diameter, together with aggregates of recrystallized quartz and occasional biotite flakes. Some contamination is indicated by the presence of occasional irregular aggregates of bright orange pinite, representing altered cordierite grains.

The recrystallization which these rocks have undergone tends to suggest their possible correlation with the gneisses and associated granodiorites, but their mineral assemblages are more closely related to those of typical younger intrusions, such as the Red Granite itself. Correlation with these younger intrusives is further supported by the fact that they are younger than the Wombat Creek beds, probably Middle Devonian, whereas the typical gneisses and granodiorites elsewhere in eastern Victoria are pre-Middle Devonian.

Miscellaneous Dykes

There are great numbers of dykes not directly associated with any of the major intrusives. They include porphyries and porphyrites, diorites, lamprophyres, dolerites and other basic rocks. There is evidence connecting the more acid dykes with the Red Granites. Again, there is a suggestion of a gradation from these rocks through diorites and lamprophyres to the basic rocks, and therefore of a connection between all these dyke rocks and the Red Granites.

Porphyries and Porphyrites

These rocks are very abundantly represented in the valleys of Bingo Creek and of Livingstone Creek and its major tributaries, and also occur in the northward extension of this belt as far as Frazer's Tableland, the Knocker and the Wombat Creek valley. In the remainder of the area, however, they are rare or absent. This distribution is one of the indications for a genetic relationship to the Red Granite, which occupies a central position within this belt, and agrees with the observations of Edwards and Easton, who describe a similar group of rocks as co-magmatic with the Red Granites of Pine Mountain and Mt. Mittamatite. In the latter areas, however, the intrusion of the dykes preceded that of the main batholiths, while in this area the relationships appear to be reversed. Several of these dykes actually cut the Ren Granite (6841, etc.), and others are closely associated with aplites and pegmatites undoubtedly derived from this mass.

Generally speaking, the rocks may be referred to as quartz porphyries and porphyrites, grading into felspar porphyries and porphyrites. If quartz occurs as phenocrysts, it is typically rounded and embayed, euhedral crystals being only occasionally found (6842). Phenocrysts of felspar tend to occur in small clusters and are commonly subhedral. Either orthoclase or plagioclase may predominate, the latter ranging from acid oligoclase, Ab_{85} (6841), to albite, Ab_{95} (6843, 6844). The grain-size of the phenocrysts is always roughly uniform in any one rock, but varies from rock to rock, 2 mm. being about the maximum observed. Phenocrysts of biotite are less common, and are typically strongly chloritized or replaced by aggregates of epidote (6845, 6846). The matrix is invariably fine-grained, consisting of quartz, felspar and biotite in varying proportions.

In the hand-specimen, the rocks are frequently seen to be faintly banded, due to slight variations in grain-size or mineral composition of the matrix, but the texture is invariably granular, and no flow structures are visible in the thin sections. A very common feature is the recrystallization of the matrix, with the development of spherulitic aggregates of secondary felspar, the original phenocrysts of quartz or felspar frequently acting as nuclei for these aggregates. In one specimen (6851), leucoxene is an important constituent of the matrix, forming pseudomorphs after ilmenite. Quartz veins, up to ·5 mm. wide, cut across some of these rocks and may be arranged randomly or in well defined parallel sets (6852, etc.).

If quartz phenocrysts are absent, plagioclase usually predominates over orthoclase, although there are a few exceptions (6853, 6854). The phenocrysts are typically albite, Ab_{95} (6855, 6856), sometimes attaining the composition of pure albite (6858). Banding is still occasionally present (6859), due mainly to variations in the amount of quartz present in the matrix.

Some rocks have a greater proportion of dark minerals and form a link with the more basic types, in which hornblende is an important constituent. Unfortunately they are frequently much altered, the original ferromagnesian minerals being replaced by chloritic aggregates, so that the presence or absence of hornblende

in the original rock is often difficult to decide (6860, 6861). At the same time epidote is developed and many of the original felspar phenocrysts are replaced by finely granular aggregates of zoisite.

The appearance of the hand-specimens of these rocks varies markedly with the degree of alteration. The least altered rocks are grey or greyish green, the pink felspar phenocrysts and deep green crystals of the ferromagnesian minerals being sharply defined from the matrix. With more advanced alteration, however, the rocks as a whole assume a speckled appearance, ranging from reddish brown to dull green, and the original phenocrysts are no longer clearly distinguishable.

Basic Dykes

With increasing amounts of ferromagnesian minerals and the loss of marked porphyritic texture, the porphyries and porphyrites appear to pass into diorites, lamprophyres and other basic rocks which comprise perhaps a quarter of all dykes of any kind in the area. They occur as dykes and small lenticular masses up to about two chains by ten, as in the lower part of Bingo Creek and near the head of the Bundarra River, but many of the occurrences are very much smaller, dykes only one or two feet thick being the most common, particularly among the more basic types.

Their distribution corresponds reasonably closely to the margins of the main gneissic masses of the metamorphic complex. With very few exceptions, they occur within two well defined areas. Of these, one occupies a belt about eight miles wide, parallel to the main schist-gneiss contact, extending in an approximately north-north-easterly direction from Omeo to Mt. Bogong. The other comprises the lower portion of the Rocky Valley and Pretty Valley branches of the East Kiewa River, especially near the Junction Dam, and may represent the most easterly portion of a similar belt on the west flank of the main gneissic belt.

Hornblende Diorites and Lamprophyres

Specimens in which hornblende was originally present in significant amounts have about the same distribution as the types discussed earlier, and in addition form important masses in two dyke-complexes, situated on the north shoulder of Mt. Livingstone and on the One-Mile Creek - Four-Mile Creek saddle of the old Wombat Creek track respectively. These complexes occupy areas of about one mile by half a mile and four miles by one mile respectively, within which only igneous rocks outcrop. The rocks, however, show great variation in composition and texture, ranging from quartz felspar porphyrites, through felspar porphyrites, to diorites, etc. Exposures are insufficient to show the relationships between the various types, and no attempt has been made to map them in detail. The size of the individual masses within the complexes ranges from a few chains to about half a mile in diameter, and the relative abundance of the various types varies from place to place.

The typical diorites are medium-grained, even-grained rocks, composed essentially of hornblende and intermediate plagioclase, with smaller amounts of iron ores, quartz and alteration products of the chlorite and epidote groups. In the hand-specimen, they have a characteristic speckled white and green appearance, with an average grain-size of between 1 and 2 mm. for most members of the group. The only exception is a rock from Bingo Creek (6872), which shows a markedly inequigranular texture with abundant micro-phenocrysts of hornblende set in a fine-grained matrix of stumpy plagioclase laths and rare interstitial quartz.

The hornblende occurs always as subhedral prismatic crystals, locally chloritized, occasionally moulded on felspar or enclosing small crystals of the same. It is typically pleochroic dark brown to pale brown, or less commonly dark bluish green to pale greenish brown, with a maximum extinction angle of 18° to 20°. In one rock (6876) zoning occurs, cores of the bluish green variety being surrounded by rims of the brownish green type. Biotite is never abundant, and if present is chloritized to about the same extent as the hornblende. Epidote is commonly present and becomes important in some rocks. Iron ores are always present, usually as scattered relatively large crystals, occasionally showing alteration to leucoxene, indicating ilmenite or titaniferous magnetite.

The plagioclase in most members of the group varies between andesine, Ab_{60}, and acid labradorite, Ab_{50}, and is typically strongly zoned. Very commonly, a clear rim is sharply set off from a strongly sericitized core, so that the change in composition cannot usually be estimated. Orthoclase is only rarely present, and is never abundant, forming relatively large, irregular grains, within which any of the other minerals of the rock may be enclosed. Quartz, varying from a major constituent to a mere trace, has a very similar mode of occurrence, and is never completely absent. In some of the more altered rocks, however, it is possible that some at least of the quartz may have been introduced subsequent to the crystallization of the rock. Some rocks of this group again contain albite, Ab_{90} to Ab_{95}, but do not appear to differ from the remaining members in any other way (6873, 6874).

The fine, even-grained rocks have no exact equivalents to the diorites, but some of the more ferromagnesian-rich porphyritic types approximate fairly closely to them in mineral composition. These include a number of rocks outcropping within or just outside the main mass of the Red Granite (6871, 6881, 6882, etc.). In these rocks, quartz is still occasionally present as small rounded phenocrysts, but more commonly it is restricted to scattered interstitial grains. Basic andesine, Ab_{50} to Ab_{60}, is characteristic of the phenocrysts (6865, 6866, etc.), but the relation of this group to the previous one is shown by the fact that albite, Ab_{95}, still occurs in some of these rocks (6862, 6870), which again show no other points of difference from the remainder of the group. Both these felspars occur as subhedral crystals up to 2mm. long, and occasionally, as in the rocks from the One-Mile Creek - Four-Mile Creek complex, the former show faint oscillatory zoning. In the more altered rocks, these felspars are completely sericitized and occasionally are crowded with minute granules of a colourless mineral of the zoisite group. The groundmass felspar is not usually determinable, occurring as squat subhedral laths of approximately uniform size within any one rock, but varying somewhat from specimen to specimen.

If both biotite and hornblende were originally present, the latter is invariably the less altered of the two. It forms abundant subhedral prismatic crystals in the matrix of all these rocks and occasionally also appears as phenocrysts (6866, 6868). The pleochroism is typically light to dark brown, but changes to greenish tints as chloritization progresses, the phenocrysts being typically affected before the smaller crystals. Biotite appears to have been restricted to the phenocrysts and is now only indentifiable by the preservation of the outline of the original flakes, having been completely replaced by fine-grained aggregates of chlorite and of a pale-brown non-pleochroic mica. Magnetite is an important constituent in one rock (6870), and pyrite has been introduced in significant amounts into another (6871).

Augite Diorites and Lamprophyres

With the appearance of pyroxenes in the hornblende diorites and lamprophyres, transition to the next group begins. These are the quartz-hornblende-augite diorites of Edwards and Easton, and the augite lamprophyres of Baker. They are characterized by the presence of variable amounts of augite as subhedral micro-phenocrysts, or irregular interstitial grains, or both. The pyroxenc is always of a diopsidic type with $2\,V = 50°$ or higher, and correspondingly high extinction angles of 40° to 45°. Occasional purplish tints are suggestive of slight enrichment in titanium (6886). A tendency to glomero-porphyritic texture is noticable in a rock from Day's Creek (6887), with the segregation of subhedral augites of about 1 mm. diameter into clots of six to eight individuals, occasionally in association with less numerous felspars of about the same size. Hornblende is always present, but may be subordinate to the pyroxene in amount. It does not differ essentially from that of the rock types previously described, and very occasionally shows mantling of the pyroxene. Typically, a gradation in size from the micro-phenocrysts to the matrix is shown by both augite and hornblende. In some rocks, however, the augite may be restricted to the micro-phenocrysts, and hornblende is the only ferromagnesian in the matrix (6885, 6889).

The groundmass felspar of these rocks occurs invariably as somewhat ragged laths, which maintain a reasonably uniform grain-size within any one specimen, but which are always sericitized beyond possibility of identification. In the same way, the micro-phenocrysts of felspar, up to 2 mm. in diameter, which were originally present in some of the rocks, have been completely altered to sericite-calcite-zoisite aggregates, and are no longer identifiable. Quartz, as in the last group of rocks, is present only as rare interstitial grains or as xenocrysts surrounded by reaction rims of epidote. Iron ores are also present in significant amounts, although usually as very small crystals.

A closely allied type is represented by non-porphyritic rocks of similar mineral composition, but with a texture dominated by the felspars (6890-6892). These felspars occur as subhedral to ragged unzoned laths, varying from about ·2 mm. to 1 mm. in length within any one specimen, and are again very sodic in composition, albite, Ab_{90} to Ab_{95}, being typical. Augite occurs either as prismatic subhedral crystals, idiomorphic against felspar, or as less regular interstitial and ophitic grains. In either case, hornblende is subordinate, magnetite relatively abundant and quartz present in very small amount as minute interstitial grains only.

Dolerites

With an increase in the amount of pyroxene and a slight change in the composition of the plagioclase, these rocks pass into the typical dolerites, best represented in this area by a series of rocks from the immediate vicinity of Omeo, especially Day's Creek and Bingo Creek. They are dark grey-green in the hand-specimen, becoming lighter on weathering. and, because of the marked ophitic texture, tend to appear finer-grained than they actually are. The pyroxene is typically a purplish, non-pleochroic, titaniferous augite with moderate 2V, 55° to 60°, and high extinction angles, 35° to 45°. Strongly ophitic grains of irregular outline are present in every specimen (6893, 6894), but occasionally a few idiomorphic crystals also occur (6895). Some of these specimens (especially 6895) show intimate intergrowths of two pyroxenes within the outlines of one subhedral crystal, the product being not unlike a coarse perthitic intergrowth in appearance.

The satisfactory determination of both members of any given pair was not possible in any of these specimens, but at least one member of each pair appears to be the normal augite of these rocks, and no orthorhombic pyroxenes appear to be involved. Hornblende is never preserved as such, but may be represented by some of the numerous chloritic aggregates which are always present. Iron ores are present in relatively small amount and have occasionally been partially replaced by leucoxene (6893). The felspars may attain a maximum length of about 2 mm., and are rather more basic in composition, labradorite, Ab_{45} to Ab_{40}, being typical. Quartz and alkali felspar are absent or very rare, except for a few rocks rich in albite, Ab_{95} (6895, etc.).

Alteration differs from that of the earlier described rocks in that calcite tends to be developed instead of epidote. One rock from Bingo Creek (6896), into which pyrite has been introduced in relatively large amount, shows a development of numerous almost spherical aggregates of a chloritic mineral, up to 1 mm. across, each surrounding a single crystal of calcite. These aggregates cut across the original textures of the rock and appear to have resulted from the indiscriminate local replacement of all the original minerals.

Basic Lamprophyres

A small group of rocks from the same localities may be referred to as basic augite lamprophyres, bearing the same relationship to the dolerites as the hornblende lamprophyres do to the diorites. They are characterized by a panidomorphic texture and by a continuous gradation in the size of all the major constituents. The felspar shows a slight gradation from labradorite, Ab_{40}, in the larger crystals to acid labradorite, Ab_{50}, in the smaller ones, although zoning is typically absent. Alteration, with the development of chlorite flakes and epidote granules, arranged along the cleavages of some of the larger crystals, is not uncommon in some rocks (6897, 6898), while sericitization is the dominant process in others (6899).

The pyroxenes rarely exceed ·5 mm. in diameter, and are similar to those of the dolerites. Hornblende is represented only by rare small needles, but may have been largely replaced to form some of the chloritic aggregates which are abundant in all rocks of this group. Others show evidence of having been derived from pyroxenes, preserving the outline of the original crystals, including a number which attain a diameter of about 3 mm. Magnetite is abundant as relatively large crystals and skeleton crystals. Quartz is present only as rare interstitial grains and as occasional xenocrysts, the latter showing reaction rims, composed of numerous minute augite and/or epidote needles growing radially inwards from the margin.

Basaltic Dykes and Monchiquites

The basaltic dykes of the area are represented by rocks from Day's Creek (6900, 6901), Livingstone Creek (6902), and the Mt. Wills-Mt. Bogong ridge (6903). In the hand-specimen, they appear blue-black, very dense and only slightly porphyritic, but in thin section they show a markedly porphyritic texture, phenocrysts of labradorite, Ab_{40}, or of diopsidic augite with minor felspar, being embedded in a uniformly fine-grained matrix of plagioclase laths, augite granules and iron ores. Extensive alteration of the felspars to sericitic aggregates and of the pyroxenes to chlorite-calcite aggregates is typical. Olivine is absent, but quartz may occur as rare interstitial grains.

A single occurrence within the area, represented by a dyke from the workings of the Maude and Yellow Girl Mine, Glen Wills, has been referred to as a monchiquite (Edwards 1938). It differs from the basaltic dykes mainly in the presence of abundant small sub-rectangular biotite flakes in the matrix, in addition to the usual plagioclase, augite and iron ores. A few felspars were originally present as phenocrysts, but these have been completely replaced by fine-grained aggregates of calcite and are no longer identifiable (6904).

The Eruptive Sequence of Alkali Rocks and Dykes

The Trachytes, Syenites, Granite Porphyries and Red Granite appear to belong to one general eruptive cycle. Close association in the field and similarity of mineral composition show that the Syenites and Trachytes are products of the same magmas, the intrusive phase following the extrusive. Transitional types between the Syenites and Granite Porphyries indicate a close relationship between these two groups and the separation of them is really somewhat arbitrary. At Mt. Little Tambo it is reasonably certain that granite porphyry has intruded trachyte, and it also appears that for the area as a whole syenite preceded granite porphyry, although Broadhurst and Campbell (1932) tentatively suggested that porphyry preceded trachyte and syenite in the Mt. Leinster complex. The Red Granite of the Knocker does not come in contact with any of these rocks and its relation to them is deduced on more indirect evidence. The Granite Porphyries intrude the Tambo Formation of probably late Middle Devonian age, which therefore is the lowest possible age for the alkali rocks.

The nearest known comparable occurrence of syenitic rocks is the Mt. Dromedary complex in southern New South Wales, described by Ida Brown (1930) as consisting of banatite (quartz monzonite), monzonite, and minor amounts of shonkinite, essexite, jacupirangite and ijolite. It is intrusive only into Lower Palaeozoic strata but is thought to be of Permo-Carboniferous age because of petrological similarities with lavas of that age occurring in the same general region. There is, however, no compelling evidence in favour of correlating the Mt. Dromedary rocks with those of eastern Victoria.

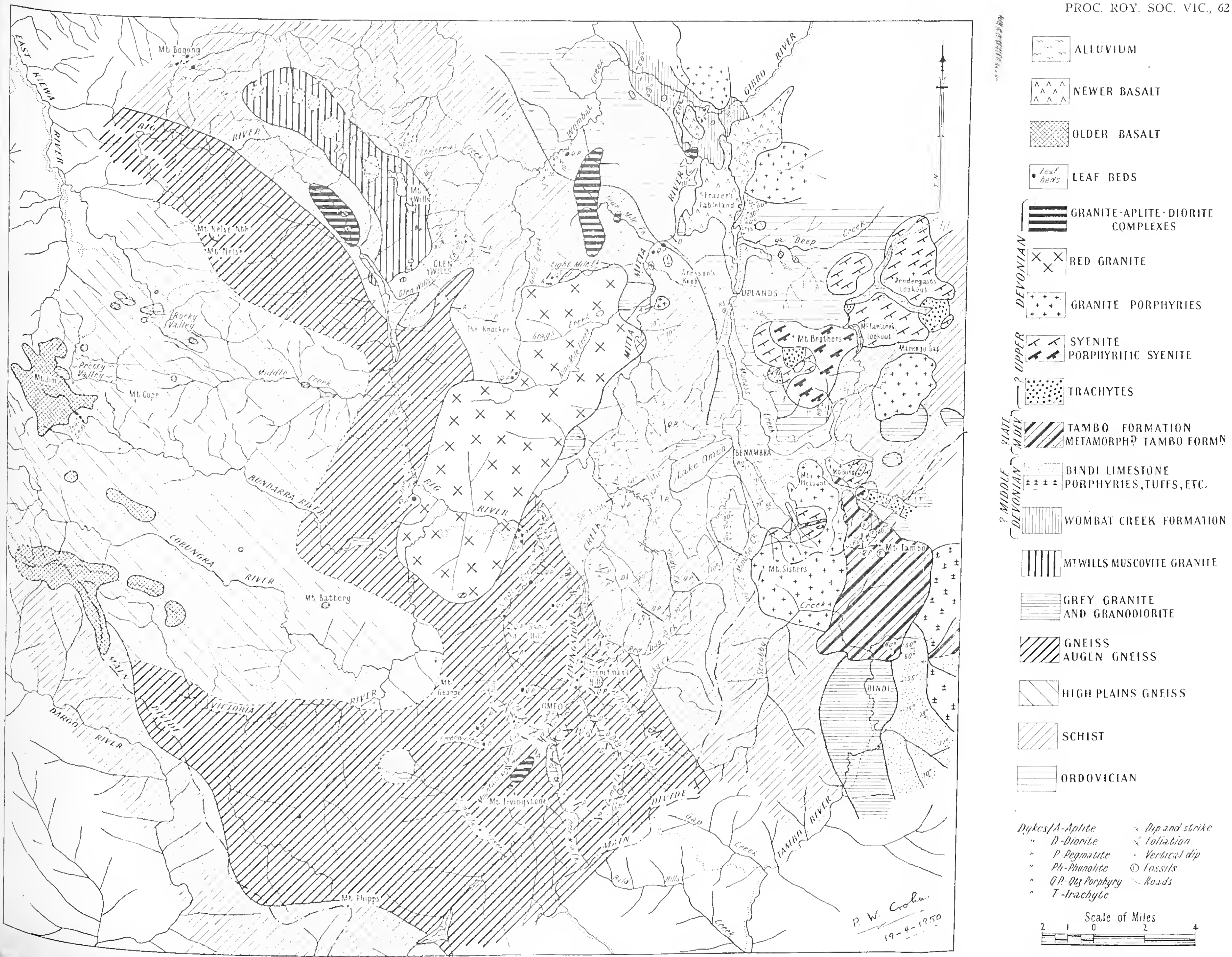
Other workers have suggested a Tertiary age for the Syenites and Trachytes, e.g., Edwards (1939), on the grounds of petrological analogy between them and the alkali rocks of central Victoria which are differentiates of Tertiary basaltic magmas. However, a correlation with the Newer Basalts is out of the question. Flows of Newer Basalt occur in the Morass Creek and Mitta Mitta valleys only about three miles from the western boundary of the Mt. Brothers complex, and their youth has been demonstrated by Hills (1939), who showed that the swamps of Uplands, six miles north of Benambra, caused by the flows blocking the valleys, are only now being drained by the cutting of a new channel through the basalt barrier. Under these circumstances the amount of erosion required to expose the syenite, which towers more than two thousand feet above the basalts, is inconceivable. Correlation with the Older Basalts is no more satisfactory. The present Mt. Leinster ridge forms part of a concordant group of summits which are thought to represent remnants of a pre-Older Basalt erosion surface. The mode of occurrence and field characteristics of the alkali rocks of the Omeo district are different to those of central Victoria and in comparison their amount seems inordinately excessive for them to be derived from Tertiary basaltic magmas.

The Granite Porphyries are probably closely related to the petrologically similar rhyolites of Mt. Burrowee and Mt. Benambra to the north. At their southern end the Mt. Benambra rocks almost come into the area covered by the present work. They overlie the rocks of the Wombat Creek Formation near the junction of Wombat Creek and the Mitta Mitta River (Kenny 1937). Edwards and Easton (1937) suggested that these rhyolites pre-dated the Red Granites of Pine Mountain and Mt. Mittamatite but were co-magmatic with them. By analogy it is not unreasonable to assume that the Red Granite of the Knocker is co-magmatic with the Granite Porphyries. This correlation is supported by the petrological similarity of the Granite Porphyries and some of the quartz-felspar porphyry dykes associated with the Red Granite.

The Snowy River Series, consisting of porphyries and porphyrites, as lavas and dykes, and pyroclastic rocks, underlie Middle Devonian limestones of Buchan and Bindi, while the Tambo Formation conformably overlies the Bindi limestones. The Snowy River Series, assigned by Samson and Cochrane (1947) to the late Lower Devonian, is therefore older than the Granite Porphyries of the Omeo district and separated from them by the time interval represented by the deposition of the Bindi Limestones and of the Tambo Formation. Further evidence of two periods of igneous activity is provided in the Limestone Creek area where the beds of the Limestone Creek Formation are both underlain and overlain by igneous rocks. The petrology of these rocks has not been described in detail, but from what is known of them they might well be the equivalents of the Snowy River Series and the Granite Porphyries respectively. The plugs of The Pilot and Mt. Cobberas in this district are composed of rocks similar to the Granite Porphyries.

These relationships assume that the strongly folded Wombat Creek and Limestone Creek Formations are of the same general Middle Devonian age as the less disturbed rocks of Buchan and Bindi. Their palaeontology is not known in detail and the more intense folding might suggest that they were older. However, the similar intensely folded beds of Tabberabbera, described by Skeats (1929) as in part Upper Silurian (Yeringian), are now known to range from horizons no lower than high in the Lower Devonian to Middle Devonian (D. E. Thomas and E. D. Gill, personal communication). At Buchan and Bindi the folding is less intense and where high dips do occur they can usually be attributed to large-scale slumping or drag along major faults. The cushioning effect of the competent lavas of the Snowy River Series probably prevented the intense crumpling which occurred in the three other areas.

The upper age limit of the alkali rocks cannot be determined in the Omeo district and indirect evidence must be sought elsewhere. At Mt. Taylor, north of Bairnsdale, there is a mass of granite porphyry comparable with those described. It comes in contact with gently dipping beds regarded as high in the Upper Devonian, which at Tabberabbera rest unconformably upon the intensely folded Middle Devonian rocks. The contact relations have not been described, but it is reported (W. Baragwanath, personal communication) that the porphyry is intrusive into the lower part of this formation, consisting of red beds and interbedded lavas, but that the upper part, consisting of grey beds without lavas, appears to overlie the porphyry unconformably. The intrusion of the porphyry would therefore certainly seem to be later than the orogeny responsible for the unconformity between the Middle and Upper Devonian and might have occurred very late in the Upper Devonian.


ALLUVIUM
NEWER BASALT
OLDER BASALT
LEAF BEDS
GRANITE-APLITE-DIORITE COMPLEXES
RED GRANITE
GRANITE PORPHYRIES
SYENITE
PORPHYRITIC SYENITE
TRACHYTES
? UPPER DEVONIAN
TAMBO FORMATION
METAMORPHD. TAMBO FORMN.
? LATE M. DEV.
BINDI LIMESTONE
PORPHYRIES, TUFFS, ETC.
WOMBAT CREEK FORMATION
? MIDDLE DEVONIAN
MT. WILLS MUSCOVITE GRANITE
GREY GRANITE AND GRANODIORITE
GNEISS
AUGEN GNEISS
HIGH PLAINS GNEISS
SCHIST
ORDOVICIAN
Dykes/A-Aplite
" D-Diorite
" P-Pegmatite
" Ph-Phonolite
" Q.P.-Qtz Porphyry
" T-Trachyte
Dip and strike
Foliation
Vertical dip
Fossils
Roads
Scale of Miles
2 1 0 2 4
T.N.
EAST KIEWA RIVER
Mt. Bogong
BIG RIVER
Mt. Wills
GLEN WILLS
Mt. Nelse Nth
Mt. Nelse
Rocky Valley
Pretty Valley
Mt. Jim
Mt. Cope
Middle Creek
The Knocker
Wombat Creek
MITTA
Gresson's Knob
UPLANDS
Frazer's Tableland
GIBBO RIVER
Deep Creek
Pendergasts Lookout
Mt. Brothers
McFarlane's Lookout
Marengo Gap
Lake Omeo
BENAMBRA
Mt. Pleasant
Mt. Bundara
Mt. Tambo
Mt. Sisters
BUNDARRA RIVER
BIG RIVER
COBUNGRA RIVER
Mt. Battery
VICTORIA RIVER
Mt. George
OMEO
Frenchman's Hill
BINDI
DARGO RIVER
MAIN DIVIDE
Mt. Livingstone
Mt. Phipps
TAMBO RIVER
Gap Creek
Haunted Hills
P. W. Crohn
19-4-1950

The age of the basic dykes and their correlation with the other eruptive rocks are rather problematical. It is not certain that they all belong to one eruptive cycle. Thus in the region of Mitta Mitta and Eskdale, and also of Wombat Creek, dioritic dykes transgress the pegmatites of the Mt. Wills cycle (Whitelaw, Kenny and Easton 1915; Kenny 1925), whereas at Mt. Bogong the relationship appears to be reversed.

Comparable rocks have been described from Swift's Creek (Howitt 1879) and the Ovens Valley (Kenny 1925). The closest analogues, however, appear to be those of north-eastern Benambra, referred to as diorite porphyrites and labradorite porphyrites by Edwards and Easton (1937), who correlated them with the Red Granite cycle and showed that their intrusion preceded that of the main masses of Red Granite at Pine Mountain and Mt. Mittamatite. In the Omeo district the Red Granite does not appear to cut off any of the dykes, and a few of the fine-grained dykes lie within the granite or transgress both granite and older gneisses. The same applies to certain of the porphyry dykes which are considered to be related to at least some of the more basic types. The dykes therefore appear to be somewhat younger than the granite.

A feature which lends some support to the idea that the dykes are connected with the Red Granite and the other alkali rocks is the presence of sodic oligoclase or albite in occasional rocks which otherwise are representative of the various types throughout the whole suite. There is no evidence that these sodic felspars are secondary.

Edwards (1937) suggested that the granites and granodiorites of eastern Victoria might be derivatives of tholeiitic basalt magma contaminated by large amounts of aluminous sediments, and that the dioritic dykes might represent an intermediate product of contamination or a differentiate of the tholeiitic magma. They would then be linked to the granodiorites through the quartz diorites of Swift's Creek (Howitt 1879) and Yackandandah (Tattam 1929), which in the Omeo district are represented by only a small mass in the valley of the Bundarra River. These quartz diorites, however, belong to the early intrusive cycle of the granodiorites and gneisses and thus the dioritic dykes would also have to be placed in this cycle. This could be reconciled with relations in the Omeo district only by admitting at least two different ages for the dykes.

The Woods Point-Walhalla dyke swarm in east-central Victoria (O. A. L. Whitelaw 1916; N. R. Junner 1920) includes most of the rock types of the Omeo district and like them is not directly associated with any plutonic rocks. In many minor features such as albitization and propylitization the dykes of the two regions correspond. Hills (*A.A.A.S. Handbook,* 1935) regarded them as related to the dacites and other rocks of the Cerberean Ranges of Upper Devonian age.

Edwards (1938) has suggested that the more basic types may belong with the Older Basalts of Lower to Middle Tertiary age. The dolerites, augite lamprophyres and basaltic rocks of the Omeo district are generally similar to those which in other parts of the State appear to be Tertiary, but outweighing this is the evidence of a gradation from them to the less basic types of undoubted Palaeozoic age.

Felspathoidal Rocks

Only a very limited number of felspathoidal rocks occur within the area. Two nepheline phonolites were described from the immediate vicinity of Omeo by Skeats (1912), and the existence of seven others was recorded in a later paper

(1921). The latter, however, were not described in detail and their localities were not given. In addition, a nepheline tinguaite porphyry was recorded by Broadhurst and Campbell (1932) from the Mt. Leinster district.

No detailed investigation of these rocks was made, but some further specimens of the phonolite dykes already described were collected and a comparison with related types from other parts of the area was attempted.

All the rocks of this group are light grey in colour, with a somewhat speckled appearance, and the majority show distinct flow-structure in the hand-specimen. Phenocrysts of blue-black lustrous aegirine and, in one case, of alkali felspar, are characteristic. On weathering, the matrix assumes a faintly reddish tinge and the ferromagnesian minerals appear distinctly green, but the appearance of these rocks is always much fresher than that of the trachytic dykes associated with the syenites of Frenchman's Hill and elsewhere.

Of the dykes previously described, the northern one (3A of Skeats) contains abundant aegirine as small prisms and irregular granules and skeleton crystals. Nepheline is rather less abundant, occurring as scattered rectangular crystals, and the felspar forms radiating or sub-parallel aggregates of lath-shaped crystals with almost straight extinction, or irregular patches and pools, enclosing either or both of the other minerals. It is untwinned, with a refractive index less than balsam (orthoclase or soda-orthoclase) (6914, 6915). The more southerly occurrence (43 of Skeats) is rather more variable in texture. Nepheline is very abundant, occurring as relatively clear crystals typically with rectangular cross-section. Aegirine forms smaller prisms (6916), or larger interstitial and poikilitic grains (6917), and is typically pleochroic, deep-green to yellowish-green. In the former specimen, alkali felspar forms small pools enclosing all the other minerals; in the latter it occurs as rather smaller laths, locally in good parallelism due to flow.

Of the other occurrences of rocks of this group recorded during the present investigation, some of which may correspond to the dykes recorded by Skeats without localities, one (6918) from the Livingstone Creek valley, about four miles north of Omeo township, closely resembles the last described rock and contains a comparable amount of nepheline. Another (6919), from the upper portion of Bingo Creek, shows rather better flow structure, and differs in containing only very rare crystals of nepheline but rather abundant patches of a colourless isotropic mineral of low refractive index, which may be sodalite or analcime. The remaining member of the group from the Omeo district is a more porphyritic rock from the valley of Mountain Creek (6920), containing tabular alkali felspars (sanidine), up to 5 mm. long, and squat prisms of aegirine up to 2 mm. long. The matrix is very similar to that of the last described rock, nepheline being again very rare, but the isotropic mineral appears to be absent.

Of the previously recorded dykes, one cuts a diorite dyke and the other a trachytic dyke probably associated with the syenites of Frenchman's Hill, but none of the newly described occurrences shows any relationships to other dyke rocks. Their age is thus only determinable within fairly wide limits and they might be assigned to the period of igneous activity responsible for the syenites, or to one of the Tertiary periods. The main reasons for assigning a Tertiary age to them are their relatively good state of preservation, contrasting strongly with that of the Palaeozoic trachytes, and their apparent correspondence with the plugs and dykes of tinguaite, phonolite, etc., of the upper Ovens valley (Skeats 1921; Edwards 1938).

This correlation is supported by the occurrence of a single related rock, almost midway between Omeo and the Ovens valley, in an area which is otherwise almost free from dykes of any description. The rock concerned is a dyke from Timm's Lookout, about one mile north-west of Mt. Nelse, consisting essentially of alkali felspar and aegirine with subordinate magnetite. The texture is micro-porphyritic, with subhedral felspars grading in size from about 1 mm. down, but the dark minerals are restricted to the matrix, where the aegirine forms long slender needles and irregular granules. Alteration is more advanced in this specimen, the felspar being strongly sericitized and the aegirine chloritized to some extent. Calcite has been introduced in patches and it is no longer possible to definitely identify any nepheline which may have been originally present (6921).

Older Basalts

The Tertiary basalts of the area fall into two distinct groups, referable to the Older and Newer periods of igneous activity respectively, and readily separated on petrological and physiographic grounds. The Older Basalts are restricted to the western portion of the area, where they occupy extensive areas on the Bogong High Plains, the main occurrences being at Mt. Jim, Ruined Castle, Basalt Hill and Roper's Lookout. These occurrences are only the northern members of a group which includes also the flows and dykes of Mt. Higginbotham, Dinner Plain, Mt. Battery, Mt. Tabletop, and the Dargo High Plains, but no opportunity was available for visiting the more southerly localities.

The main outcrops are recorded by Murray (1878) and Hunter (1909), and the petrological types represented are listed by Edwards (1938).

As already indicated, their distribution, and that of the associated Deep Leads, shows that they were extruded at a time when a mature topography with maximum relief of the order of 800 feet to 1000 feet was in existence. Previous workers have regarded the general southward decrease in the level of the various occurrences as evidence for the position of the pre-Older Basaltic Divide to the north of the present Divide, but if part or all of this change in level is ascribed to post-Older Basaltic tilting (see above), this evidence cannot be relied upon. An alternative method would be to use the local relief at the time of extrusion, measured by the difference in level between the base of the flows and the highest preserved remnants of the pre-Older Basaltic surface in the vicinity. Taking this relief at any point as a measure of its distance from the pre-Older Basalt Divide, results in general agreement with the older method are obtained, the values showing a general increase southwards from Mt. Fainter and reaching a maximum at the southern extremity of the Dargo High Plains.

At most of these occurrences, several flows can be distinguished in the field, either by abrupt changes in level as at Basalt Hill, or by variations in jointing and macroscopic appearance as at Mt. Jim. At the same time, the rocks show fairly constant textures and mineral assemblages, and only a very limited number of types appear to be represented. Vesicular types are almost absent, and amygdales are only rarely found, e.g., south of Mt. Jim. The rocks vary from deep blue-black to bluish-grey, the finer-grained types being usually the darker. Phenocrysts of olivine are always visible in the hand-specimens, and occasionally are accompanied by slightly smaller augites or felspars, or both.

At Mt. Jim, centrally situated on the Bogong High Plains, at least four distinct flows can be recognized and the total thickness exceeds 500 feet. The dominant

type contains abundant subhedral olivines and less numerous augites, both up to 1 mm. in diameter, the former occasionally altering to serpentine along cracks and margins, in a matrix of labradorite laths, Ab_{50}, magnetite crystals and small interstitial augite granules (6922, 6923). Glass is almost absent and flow structure only faintly developed. The highest flow, forming the summit itself, is similar in mineral contents, but has a rather finer-grained matrix and tends towards a glomero-porphyritic texture in places (6924). On the southern edge of the mass, in the upper portion of the Bundarra River valley, another type becomes important, in which the phenocrysts are less sharply marked off from the matrix, subhedral crystals of olivine and slender laths of labradorite grading from about 1 mm. down to the grain-size of the matrix, which consists almost entirely of augite prisms and granules, together with subordinate magnetite and relatively abundant interstitial green glass (6925) (Berwick type ? of Edwards).

At Basalt Hill, about six miles north-east of Mt. Jim, three flows only are represented, and the total thickness does not exceed 150 feet. The lowest two flows are rather fine-grained types, containing rounded to subhedral olivines and augites, both up to 2 mm. in diameter, the former frequently altering to serpentine or iddingsite. The matrix again consists of felspar laths, augite granules and magnetite cubes (6926), together with a certain amount of brownish glass in one specimen (6927) (Buckland type ? of Edwards). The top flow is similar in composition, but contains only micro-phenocrysts of olivine, up to 1 mm. in diameter, in a very much coarser matrix of labradorite laths, Ab_{45}, augite granules and interstitial brown glass. Another specimen from the southern extremity of the same mass contains both olivine and augite phenocrysts, together with laths of labradorite, Ab_{50}, all in a fine-grained matrix of augite, plagioclase and magnetite (6928). In this rock the augite tends to be zoned, with slightly purplish cores surrounded by colourless rims, and a glomero-porphyritic texture tends to be developed.

At Ruined Castle, two miles west of Basalt Hill, the rocks correspond closely to the lower flows of the latter locality, except for a slight decrease in the number of augite phenocrysts (6929).

A specimen from Mt. Fainter, five miles further west again, collected by the late Mr. D. McCance, is also very similar, but augite phenocrysts are now completely lacking and a certain amount of flow structure is indicated by a tendency towards parallel arrangement of the plagioclase laths (6930).

This petrological similarity, together with the alignment of these three occurrences on an almost straight line with a gentle fall to the east, and the absence of any intervening remnants of the pre-Older Basaltic land surface, very strongly suggest that they are portions of a single flow or group of flows. This is a departure from the north-south trend usually assumed for these flows by previous workers (Hunter 1909, Murray 1916, etc.) and is of interest in that it coincides with the direction of many present-day topographic features in the vicinity, such as the upper portions of the Bundarra River, Cobungra River and Middle Creek valleys.

The only other basalt occurrence investigated in the High Plains area is the plug or neck of Roper's Lookout, about four miles north-west of Basalt Hill. This mass occupies an area of about 80 yards by 200 yards elongated approximately in a north-south direction, and situated on the upper portion of the steep slope which here forms the east wall of the 800-ft. gorge-like valley of the East Kiewa River. It is composed entirely of a rather fine-grained, dense, blue-black basalt, containing

scattered phenocrysts of olivine, up to 2 mm. in diameter, in a matrix composed essentially of small prisms and granules of augite, subordinate laths of unidentified plagioclase and cubes and grains of magnetite (6931-6933).

These rocks show very well the various stages in the assimilation of arenaceous xenoliths, which, to a lesser extent, may also be observed in many of the specimens described earlier. The tendency is for small augite prisms to grow radially inwards from the margins, and occasionally also along cracks and grain boundaries of the larger xenoliths. At the same time portions of the still unreplaced quartz grains become cloudy and finally isotropic, which may be ascribed to melting and the formation of a super-cooled glass. The final stage, following on complete replacement, is the dispersal of the resultant clot of augite prisms, leaving no trace of the process beyond a slight concentration of this mineral.

Sub-basaltic Deposits

Sub-basaltic and inter-basaltic gravels and leaf-beds have been recorded from numerous localities in the Dargo High Plains and from the Mt. Higginbotham-Dinner Plain group of flows (Murray 1878, Hunter 1909, etc.). However, the only occurrence within the area dealt with in the present investigation is that from the headwater region of the Bundarra River, about two and a half miles south-east of Mt. Jim.

At this locality, a series of cliff sections in the river banks reveals a minimum thickness of about 30 feet of apparently lacustrine deposits. They underlie the main series of basalts, and appear to rest directly on the basement of schist and gneiss, but they contain occasional water-worn boulders of massive basalt, indicating that flows in adjacent areas preceded their deposition.

In the largest exposed section, the succession is as follows:

12′ of sandy clays, micaceous in part, interbedded with tuffaceous beds and containing a number of soil horizons with roots *in situ*, as well as scattered water-worn fragments of fossil wood and occasional boulders of basalt. Veinlets and radiating aggregates of relatively coarsely crystalline calcite are abundant in these beds, but much of the wood is sufficiently well preserved to reveal detailed structure in thin section.

2′ of grey clays with poorly preserved leaf and stem impressions.

1′ of reddish or greyish shales with very well preserved leaf impressions, probably comprising not less than eight or ten species altogether.

1′ of brown coal, strongly laminated, preserving numerous stem and leaf impressions, somewhat oxidized where exposed to the atmosphere.

4′ of sandy clays and sands without any recognizable traces of fossils.

Dr. Patton of the Botany Department, University of Melbourne, kindly undertook the identification of the wood from the lowest beds of the series and tentatively referred it to either of the genera *Phyllocladus* or *Dacrydium*.

No identification of the leaf impressions has been attempted, and the only records from this locality are those of Murray (1878), who lists *Taeniopteris tenuissime striata; Lastrea dargoensis, = Dryopteris dargoensis* (?); and fragments of dicotyledonous leaves.

A proximate analysis of the coal from this locality was prepared by the Metropolitan Gas Company and gave: Moisture, 12·55%; ash, 2·11%; volatiles, 52·35%; fixed carbon, 32·99%. Recalculated to a dry, ash-free basis, this gives: Volatiles, 61·3%; fixed carbon, 38·7%.

Disregarding the low moisture contents, which must be ascribed essentially to drying-out of the coal at the exposed face of the seam, the composition differs only

slightly from that of typical coals from the Latrobe valley or the Altona-Bacchus Marsh fields. The difference is in the direction of increasing volatile contents and decreasing fixed carbon, ascribed by Edwards (1945) to an increase in the pollen contents of the coal.

Altogether, although providing no new evidence for the age of these deposits and hence of the basalts associated with them, the features described above support a correlation with sub-basaltic and inter-basaltic leaf beds and brown coal deposits elsewhere in the State, for which an Upper Oligocene-Lower Miocene age is generally accepted (Singleton in *A.A.A.S. Handbook,* 1935, etc.).

Some of the more southerly occurrences of sand and gravel have been worked for gold at various times, but the Bundarra River deposit, being lacustrine rather than fluviatile in origin, would not be expected to be economically workable, and has, apparently, never been tested.

Newer Basalts

Newer Basalts are more restricted than the Older Basalts, forming a single group of flows at Frazer's Tableland and its immediate vicinity. These flows appear to have occupied the valleys of the Mitta Mitta and Morass Creek prior to the development of the gorges in which these streams now flow, and attain a maximum thickness of at least 450 feet in the Morass Creek valley east of the Tableland. Apart from the main occurrence, these rocks are represented by sporadic outliers in the valley of Deep Creek and on the flanks of the lower portion of the Mitta Mitta, Wombat Creek and Gibbo River valleys.

The damming back of Morass Creek behind these flows has given rise to the alluvial deposits of the present-day Benambra flats, over much of which swampy conditions still prevail, and has been cited by Hills (1938) to demonstrate the relatively recent date of the flows.

A number of flows can be distinguished in the field, but it does not appear possible to distinguish the various members of the series on petrological grounds. Vesicular types are common, and the rocks are typically bluish-grey to bluish-black in appearance, varying from medium to fine-grained.

The petrology has been described by Hills (1939), who distinguishes two main types. The rocks corresponding to his olivine-iddingsite basalts contain phenocrysts of subhedral to sub-rounded olivine, up to 2 mm. in diameter, in various stages of alteration to iddingsite. The matrix is relatively coarse-grained, consisting essentially of laths of basic andesine, Ab_{50}, granules and small prisms of augite and platy or acicular crystals of iron ore, together with traces of an interstitial colourless material, which may be alkali felspar or a felspathic glass (6934-6936).

The rocks referred to as olivine basalts are rather finer-grained, with phenocrysts of unaltered olivine and micro-phenocrysts of unidentified plagioclase in a matrix of augite granules, smaller plagioclase laths, very finely divided iron ores and relatively abundant interstitial colourless glass, crowded with particles of iron ore. Occasional patches of greenish chloritic or serpentinous material of reddish-brown (?) iddingsite also occur, and locally take the place of the glassy base (6937, 6938).

A related type from the Gibbo River valley, occurring as a dyke or small plug, combines many of the features of both the above types. Unaltered olivines, up to 1 mm. in diameter, are set in a coarse-grained matrix consisting of labradorite laths, Ab_{50}, augite prisms and granules, crystals of iron ore and interstitial patches

of glass or of chlorite or iddingsite (6939). Occurring about 400 feet below the level of the nearest flows at that particular locality, it may have acted as a feeder for one or more of the latter.

Sub-basaltic gravels have been recorded from a number of localities (Dunn 1907; Murray 1908), and are well exposed along the Benambra-Corryong road on the southern slopes of the Gibbo River valley. They have been worked for gold with indifferent success, but possess no features of special interest.

Ore Deposits

Gold has been the most important mineral product of the area over the past sixty years, but production is now limited to a very small number of mines. Lodes have accounted for the greater part of this and those of the area and neighbouring regions fall into three well-defined groups.

In the first group are the gold and tin lodes of Glen Wills and the upper portion of Wombat Creek, which are the southerly continuation of the Eskdale-Mitta Mitta field. They comprise pegmatites, greisens and quartz reefs, associated with the Mt. Wills muscovite granite, and concentrated in a belt, 60 to 80 chains wide, parallel to the boundary of the latter (Stirling 1899; Lidgey 1895; Dunn 1906). Tin and gold are occasionally obtained from the same lode, but more commonly the tin occurs in dykes and lenticles of greissen or pegmatite, while the gold is found in quartz veins, both of the replacement and the fissure-filling types, usually in association with varying amounts of pyrite, arsenopyrite and the sulphides of copper, lead, zinc and antimony (Watson 1938; Kenny 1941). The only mine now working on this field is the Maude and Yellow Girl at Glen Valley, which had yielded a total of 60,000 oz. up to 1940, and was then crushing ores of an average value of 8 to 11 dwt. per ton.

The lodes of the Omeo-Cassilis-Swift's Creek belt form the second well-defined group. They cannot be correlated with any of the major intrusions of the area, but their distribution shows a close control of structural features. Those near Omeo, the Gambetta, Polar Star and Thistle Mines in Dry Gully, the Silver King in Livingstone Creek and the Comstock Lodes in Three-Mile Creek, all lie on a major shear zone running approximately N.W.-S.E., parallel to the main schist-gneiss contact of the area, and characterized by the abundant development of augen gneisses from originally massive igneous rocks. The individual reefs worked in the various mines, on the other hand, typically strike a few degrees east of north, or roughly at 45° to the trend of the belt as a whole, indicating an *en echelon* arrangement. The same zone, if extended to the south of the Divide, would also pass through the centre of the group of mines clustered around Cassilis and Swift's Creek, but time did not permit tracing it into that area.

These lodes are invariably heavily mineralized and commonly carry silver as well as gold. Pyrite is the dominent sulphide in the Dry Gully group of mines, while arsenopyrite is more abundant at the Silver King. Easton (1936) also records jamesonite and galena from the latter locality, and Stillwell (1933 and 1937) records pyrite, arsenopyrite, chalcopyrite, sphalerite, galena and pyrrhotite from the Swift's Creek and Cassilis lodes. The order of introduction of the ore and gangue minerals can occasionally be reconstructed from polished sections. Thus three stages can be distinguished in the mineralization of the Dry Gully group of lodes. The matrix is a quartz-epidote gangue, which may have been derived from a diorite dyke by alteration *in situ*, or may have been introduced as such. The

sulphides, and presumably the gold, form veinlets and lenticles within this, and a third stage is represented by stringers and patches of barren quartz, which cut across the pre-existing structures. The genesis of the Silver King group of lodes has followed a very similar course, but the matrix, being derived from schist and gneiss rather than from a diorite dyke, is comparatively poorer in epidote and richer in sericite. None of these mines is now working.

The third group, although outside the area proper, is included here for comparison. It comprises the reefs and lodes of the upper Cobungra and Diamantina valleys, including the Red Robin on Machinery Spur, about one mile north of Mt. Loch, and the One Alone on the Diamantina River. These reefs, on the whole, are far less mineralized than the preceding group, especially the Red Robin, in which sulphides are almost absent, and are not restricted to any definite belt or zone. The Red Robin is the only member of this group being worked at present.

Alluvial gold has also been worked at numerous localities, although none is being won at the present time. Such workings include deposits of the present erosion cycle, as in Deep Creek, Livingstone Creek and Glen Wills Creek, as well as old high-level river gravels, as in Livingstone Creek, Dry Gully and the Big River. The working of deep leads has also been of some importance at various times. Old workings include sub-Older Basalt sands and gravels at Dinner Plain, Brandy Creek and the Dargo High Plains, as well as sub-Newer Basalt gravels at Wombat Creek and the Gibbo River.

Small and unimportant deposits of copper, silver, lead and zinc sulphides, oxidized in part to carbonates, etc., have been recorded from the Wombat Creek and Limestone Creek Formations.

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The maps were redrawn for publication by Mr. D. McInnes of the Mines Department, Victoria, and, in the absence of the author on field work, the paper was edited and in part re-written by Associate Professor C. M. Tattam.

Table 1.—Heavy Mineral Analyses.

	Day's Creek. Granodiorite. 939	Livingstone Ck., S. of Omeo. Granodiorite. 943.	Frazer's Tableland. Granodiorite. 936.	Mt. Leinster. Granodiorite. G. Baker, 1941	Rocky Valley (= Tawonga). Granodiorite. G. Baker, 1941	Livingstone Ck., N. of Omeo. Granite. 932	Bundarra River. Quartz Diorite. 934.	Blue Duck. Red Granite. G. Baker, 1941	Mt. Wills. Muscovite Granite. G. Baker, 1941	Mt. Brothers North. Syenite (Monzonite). 935	Mt. Brothers South. Syenite (Na-Granite). 933	Frenchman's Hill. Syenite (Na-Granite). 940	McFarlane's Lookout. Syenite. 938	Mt. Bung Bung. Syenite. 937	Marengo Gap Hill. Granite Porphyry. 941	Mt. Sisters. Granite Porphyry. 942
Andalusite ..	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—
Apatite, colourless	r	o	o	c	c	r	o	o	o	o	o	r	o	r	r	r
pale yellow green	V	—	V	—	—	—	—	—	—	V	—	V	—	—	—	—
pleochroic cores	—	—	V	V	—	—	—	—	—	—	—	—	—	V	V	—
Augite	—	—	—	—	—	—	—	—	—	—	—	—	o	—	—	—
Biotite	A	A	A	A	a	A	a	a	V	A	A	o	r	V	o	o
Chlorite	o	c	r	o	o	o	o	o	—	V	V	V	V	V	o	V
Epidote	V	c	V	o	o	V	c	V	V	—	—	—	r	—	—	—
Fluorite	—	—	—	—	—	—	—	r	—	—	—	—	—	r	c	r
Garnet	—	—	—	—	—	a	—	c	a	—	—	—	—	—	—	—
Haematite ..	—	—	—	—	—	—	—	o	—	—	—	—	—	—	—	—
Hornblende ..	V	—	—	o	—	—	o	—	—	c	a	c	a	a	—	—
Limonite	—	—	—	—	—	—	—	c	—	—	—	—	—	—	—	—
Magnetite ..	c	a	o	a	c	c	a	a	—	a	a	A	A	A	A	A
Orthite	—	—	—	—	—	—	—	V	—	—	—	—	—	—	—	—
Rutile	—	—	—	—	—	—	—	—	V	—	—	—	—	—	—	—
Sillimanite ..	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sphene	—	—	V	r	—	—	—	—	—	V	r	—	V	—	V	V
Sulphides	—	V	—	V	—	—	V	V	V	V	V	—	—	—	—	—
Tourmaline ..	V	—	—	—	—	—	—	—	a	—	—	—	—	—	—	—
White Mica ..	a	o	r	—	A	c	c	o	A	o	o	V	r	V	c	c
Zircon, colourless	V	r	r	o	r	r	r	r	—	V	V	r	V	r	V	V
w. inclusions ..	r	V	V	c	c	r	V	o	—	r	r	o	V	o	r	o
pale yellow ..	V	—	r	—	—	V	V	o	—	r	—	V	V	r	V	V
torpedo habit ..	—	—	—	V	V	—	—	—	—	—	—	—	—	—	—	—
Zoisite	—	—	—	—	V	—	—	—	—	—	—	—	—	—	—	—
Index Number ..	19·3	12·6	19·4	7·3	18·4	5·5	10·2	2·3	2·4	14·6	9·4	5·8	3·9	11·9	3·1	1·7

A: very abundant
a: abundant
c: common
o: occasional
r: rare
v: very rare
x: seen in thin section only

TABLE 2.—MICROMETRIC ANALYSES.

	Day's Creek. Granodiorite. 6661	Livingstone Ck.; S. of Omeo. Granodiorite. 6662	Livingstone Ck.; S. of Omeo. Granodiorite. 6663	Frazer's Tableland. Granodiorite. 6664	Rocky Valley. Granodiorite. 6665	Rocky Valley. Granodiorite. 6666	Rocky Valley. Granodiorite. 6667	Mt. Leinster. Granodiorite. Broadhurst and Campbell, 1932	Livingstone Ck.; N. of Omeo. Granite. 6673	Bundarra River. Quartz Diorite. 6672	Glen Wills. Musc. Granite. 6697	Glen Wills. Musc. Granite. 6715
Quartz	40·0	37·8	35·9	35·8	28·4	36·8	30·1	32·1	34·0	17·9	74·1	41·0
Orthoclase	16·7	2·7	4·9	4·3	6·6	2·7	2·3	15·1	32·2	4·4	—	—
Micro-perthite	—	—	—	—	—	—	—	—	—	—	8·9	32·1
Plagioclase	25·7	42·6	43·5	40·0	42·0	40·2	48·2	40·6	25·1	52·5	10·7	8·5
White mica	4·8	Tr.	2·6	—	4·3	3·8	·3	—	5·2	·4	4·9	18·0
Biotite	10·6	16·2	11·0	19·4	17·7	15·2	17·6	7·2	4·5	9·8	—	—
Hornblende	—	—	—	—	—	—	—	5·2	—	10·7	—	—
Augite	—	—	—	—	—	—	—	—	—	—	—	—
Chlorite	2·0	Tr.	1·5	·3	·4	·5	·8	—	Tr.	·6	—	—
Epidote	—	—	·2	·4	Tr.	·9	·7	—	—	1·4	—	—
Cordierite	·3	—	—	—	—	—	—	—	—	—	—	—
Garnet	—	—	—	—	—	—	—	—	·4	—	—	—
Fluorite	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	—	—	—	—	—	—	—	—	—	—	1·3	·3
Magnetite	Tr.	·7	·3	Tr.	·6	—	Tr.	—	Tr.	2·2	—	—
Sphene	—	—	—	—	—	—	—	—	—	—	—	—
Apatite	—	Tr.	Tr.	—	Tr.	Tr.	Tr.	—	—	Tr.	—	—
Zircon	—	—	—	—	—	—	—	—	—	—	—	—
Sulphides	—	—	—	—	—	—	—	—	—	—	Tr.	Tr.
Matrix: Quartz	—	—	—	—	—	—	—	—	—	—	—	—
Matrix: Felspar ..	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 3.—MICROMETRIC ANALYSES.

	Mt. Brothers, N. portion. Syenite. 6795	Mt. Brothers, N. portion. Syenite. 6796	Mt. Brothers, S. portion. Syenite. 6797	Frenchman's Hill. Syenite. 6804	Frenchman's Hill. Syenite. 6805	Mt. Bung Bung. Syenite. 6802	McFarlane's Lookout. Syenite. 6792	McFarlane's Lookout. Syenite. Broadhurst & Campbell, 1932	Marengo Gap Hill. Granite Porphyry. 6824	Marengo Gap Hill. Granite Porphyry. 6825	Marengo Gap Hill. Granite Porphyry. 6826	Mt. Sisters. Granite Porphyry. 6827	Mt. Sisters. Granite Porphyry. 6828	Marengo Gap Hill. Granite Porphyry. Broadhurst & Campbell, 1932	Glen Wills Highway. Red Granite. 6733	Hinnomunjie Bridge. Red Granite. 6735	Knocker, W. slope. Red Granite. 6738
Quartz	13·4	9·8	24·1	22·5	17·2	1·9	—	Tr.	8·8	13·2	10·1	9·0	3·2	24·8	42·9	38·6	34·2
Orthoclase	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Micro-perthite	47·5	42·5	38·5	75·8	72·4	91·6	95·9	90·9	19·0	35·0	19·2	37·6	31·9	2·5	49·5	51·2	42·5
Plagioclase	26·3	31·4	23·6	1·0	·6	—	—	—	18·7	7·0	4·3	1·2	Tr.	8·0	7·1	8·5	19·9
White mica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Biotite	4·3	4·2	9·4	—	·5	—	Tr.	—	5·7	2·0	2·5	1·5	·8	4·1	·5	·8	3·2
Hornblende	7·8	11·1	3·4	—	Tr.	5·7	1·7	5·6	—	—	—	—	—	—	—	—	—
Augite	—	—	—	—	—	—	·7	1·3	—	—	—	—	—	—	—	—	—
Chlorite	—	—	Tr.	—	—	·3	—	—	—	·4	—	—	—	—	—	—	—
Epidote	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cordicrite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garnet	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fluorite	—	—	—	—	—	—	—	—	—	—	Tr.	—	·3	—	—	—	—
Tourmaline	—	—	—	—	—	—	—	—	Tr.	—	—	—	—	—	—	—	—
Magnetite	·7	·9	1·0	·8	9·3	·4	1·0	1·9	Tr.	Tr.	—	·7	·7	—	—	1·0	—
Sphene	—	—	—	—	—	—	Tr.	·3	—	—	—	—	—	—	—	—	—
Apatite	Tr.	Tr.	Tr.	—	—	Tr.	Tr.	Tr.	—	—	—	—	—	—	—	—	—
Zircon	—	Tr.	—	—	—	Tr.	—	—	—	—	—	—	—	—	—	—	—
Sulphides	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Matrix : Quartz ..	—	—	—	—	—	—	—	—	22·6	15·8	25·2	20·6	27·4	16·1	—	—	—
Matrix : Felspar ..	—	—	—	—	—	—	—	—	25·1	26·7	38·7	29·4	35·7	34·5	—	—	—

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2

ON THE TERMINOLOGY AND CLASSIFICATION OF SHORE PLATFORMS

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[Read 14 July 1949]

Abstract

The present terminology of the two main shore platforms (the high-level horizontal one or group and the low-level sloping one) is considered and criticized as incorrect or inadequate. A new terminology and classification of the various forms of the platforms as at present known are suggested for consideration and discussion.

Contents

Historical

For some years past considerable attention has been paid to the form and origin of the rock platforms which almost everywhere occur at the junction of sea and land. Two types are recognized, one being the low-level platform, which, sloping seaward, extends far out from the land; and the other being the narrow, horizontal or sub-horizontal high-level platform which is usually exposed at low tide, and which, at its seaward edge, passes, in some places abruptly, but in others gently downwards, into the first-named platform.

N. M. Fenneman (1902) used the term 'normal profile of equilibrium' for the combined low-level platform and the sediments deposited upon its outer portion.

Bartrum (1926) accepted the lower platform as the 'normal' one in deference to what he considered Fenneman's priority. In that paper Bartrum referred to the upper platform as an 'abnormal' platform in contradistinction to 'normal,' but he made it clear that it was the normal product of shore-line erosion. Certain types of the upper platform were described by Bartrum as 'storm-wave' platforms, which term was apparently introduced by him.

The writer (1931), in a brief description of some of the platforms in and adjacent to Port Phillip Bay, Victoria (being the first Victorian shore platforms

described so far as known), referred to the upper and lower platforms as the high-level and low-level platforms respectively.

Later the writer, in the course of recording his field observations, began to term the upper platform the 'normal' platform, it being so widespread, inadvertently overlooking (although previously aware of) Fenneman and Bartrum's earlier use of the term 'normal.' The lower platform the writer (1939) termed the 'ultimate' platform. In his Mt. Martha paper (1940), he divided the ultimate platform into primary and secondary ones, according to whether the lower platform was or was not formed without the intervention of the upper one.

Bartrum in a later paper (1935) again used the term 'storm-wave platform' for those platforms included in the upper horizontal or sub-horizontal group which he found at varying heights above ordinary high-tide level, and which were composed of certain classes of rocks of what may be termed a non-structural character (that is, in the main, not possessing bedding planes at or close to the horizontal). Bartrum's storm-wave type would not apply to any platforms cut below ordinary high-tide level, and his 'Old Hat' type would not apply to those platforms at a similar level which could be shown to be the result of cliff-cutting by marine abrasion.

Douglas Johnson (1931), in a discussion as to the origin of Bartrum's storm-wave platforms, did not use that term but included them in his 'two-metre benches.' He explained that such benches normally had their inner margins from a few centimetres up to two metres or more above the level of ordinary high tides, being careful to point out that the exact level varied with conditions of exposure to storm waves, tidal range, breadth of platform and other local conditions, and that the cutting was effective in unweathered rock. He concluded that the true two-metre bench was a normal feature of the present shore.

E. S. Hills (1940) showed that a platform of the upper type at Ricketts Point, Port Phillip Bay, Victoria, had developed along the upper surface of a resistant sedimentary bed, thus recognizing the importance of geological structure in the formation of platforms.

Edwards (1941) applied the term 'storm-wave platform' to all more or less horizontal platforms (other apparently than Bartrum's 'Old-Hat' type) that were distinct from the lower platform, which he termed (following Bartrum and, to some extent, Fenneman) the normal platform. He objected to the writer's use of 'normal' for the upper platform on various grounds with which the writer does not agree, but which need not be discussed here, since the writer proposes, apart from Edwards' criticism, to abandon the use of 'normal' for both classes of platforms.

C. A. Cotton (1942) describes a platform akin to Bartrum's storm-wave one, without giving it a definite name, merely referring to it as a high-water platform, but pointing out that such a platform is so commonly present on shores exposed to heavy surf that it must be regarded as a normal feature, developed by cliff-making processes.

The writer, in a paper on the shore platforms of Flinders, Vic. (these *Proc.*, Vol. 60), recognized that 'normal' and 'ultimate' were not the most suitable terms but that, in the absence of better ones, they were retained for the time being. He suggested that the terms 'upper horizontal platform' and 'lower sloping platform' in replacement of 'normal platform' and 'ultimate platform' respectively were more suitable from the descriptive aspect, but he considered that they were clumsy and were therefore rejected. Similar terminology was used by him in papers on the shore platforms of Lorne, Victoria (1949a) and Point Lonsdale, Victoria (1949b).

Objections to the Terminology Hitherto in Use

(1) Normal Platform. As a designation for either the high-level horizontal or the low-level sloping platform it is correct, because in the writer's opinion both platforms are normal products of marine erosion, notwithstanding that one (the sloping one) is practically attached to every coast and permanent so long as there is no change of sea-level, whilst the other (the horizontal one) is not universal, needing as it does certain special conditions for its production and maintenance. If, however, it is desired to distinguish by name the two platforms, then 'normal' for one alone is unappropriate.

(2) Ultimate Platform. There are two possible objections to the use of this term for the sloping platform. (a) 'Ultimate' implies that that platform has always developed from an earlier platform, but this is not always, or perhaps even commonly, the case. Strictly speaking, it applies only to the writer's secondary type of the sloping platform. (b) It may be taken to mean by some observers that it is the platform's final form and that it suffers no further change, which was certainly not the writer's view when he first used the term, nor is it now. Whilst sea-level remained constant, those parts of the platform which were not covered by marine deposits would be lowered so long as the sea was capable of eroding it. Subject to that qualification, however, its form would remain substantially the same, and it would have no successor. Hence this second objection has really no validity, but at the same time it is wise to remove any possible misunderstanding by changing the term, especially if one more expressive of the nature of the platform can be obtained.

(3) Two-metre Bench. Douglas Johnson applies this term only to benches above ordinary high-water mark. It therefore does not include horizontal benches formed below that mark and hence must be excluded as a term applicable to all benches of the horizontal type.

(4) High-water Platform. C. A. Cotton's name is not sufficiently explicit. It does not state the nature of the platform (horizontal or sloping) or its relation to high-tide level.

(5) Storm-wave Platform. The limitations with which Bartrum uses this term have been noted under 'Historical.'

The type of platform produced by storm-waves alone could doubtless also be cut when the spring tides are very high, or when there is a heavy groundswell and there are no storm-waves present, in either of which events it would be difficult to determine the origin of the platform. Moreover, storm-waves are probably the greatest factor in the formation of almost all types of the horizontal platform. Hence the term 'storm-wave platform,' as defined by Bartrum, should be relegated to a comparatively minor place in the classification.

Edwards appears to consider all the horizontal group (except of course the water-levelling and solution platforms of Wentworth referred to below) as formed by storm-waves, which differs from Bartrum's definition, and which, as used by Edwards, is an unsuitable term, in view of the fact that platforms of the class mentioned can be cut by waves which are not storm-waves.

(6) Lower Sloping Platform and Upper Horizontal Platform. These terms, as already stated, were rejected by the writer.

(7) Low-level Sloping Platform and High-level Horizontal Platform. These terms have suggested themselves to the writer, but they are cumbrous and, furthermore, he finds that the terms 'low-level' and 'high-level' are required for some of the subdivisions of the upper platform.

Classification of Platforms

From the foregoing it seems to the writer that a new terminology, involving a classification of platforms, is required. He regards the fundamental distinction to be between the horizontal platform and the sloping platform. Where both occur together, the horizontal platform is always above the sloping one.

The latter is always present, which is not true of the former. The sloping platform is also of vast extent compared with the horizontal one. The writer has therefore decided to use the terms 'major' and 'minor' to describe the respective platforms. These are not altogether satisfactory, but they do indicate, to some extent at least, the profound difference between the two types. They can, of course, be broken up as desired.

There is little known yet about the major platform, but a growing body of information is available as regards the minor platforms, the reason being, of course, their availability for examination.

The table below is submitted as a provisional one for consideration and discussion. It will probably require much modification as new facts and ideas are brought forward regarding shore platforms.

Classification

1. THE MAJOR PLATFORM
   - (i) Primary.
   - (ii) Secondary.
2. THE MINOR PLATFORMS
   - (i) 'Old-Hat' type.
   - (ii) Wave-erosion types.
   - (iii) Spray-erosion types.
   - (iv) Water-levelling type.
   - (v) Solution type.

Appended are some details of these various types.

1. THE MAJOR PLATFORM

This is the platform shown for many years past in practically all geological text-books as the only platform abutting sea-cliffs. Its characteristic feature of sloping downwards gradually from the cliffs for an indefinite distance is well known. Where, however, a minor platform is present, the major platform commences from the seaward edge of the minor platform.

Most major platforms would not be controlled structurally because, even though they were composed of bedded rocks, their dip would have to coincide with the angle of slope of the platform, which would probably rarely occur. Thus the bedded rocks would generally be truncated, and consequently the platform would not coincide with a structural plane.

The writer (1940) has made a primary and a secondary division of the major platform.

(i) PRIMARY PLATFORM. The characteristic of this type is the absence of a minor platform between the shore and the landward edge of the major platform (Fig. 1). Of course, it is difficult to say that, although the former does not now exist, it has never existed. It may have been destroyed, owing to the more rapid retreat of its seaward edge than its landward advance. Thus, what may appear to be a primary platform is really, in places, a secondary one with the evidence of its origin removed. Where, however, from the nature of the rocks, the possibility of the former existence of a minor platform is remote, the major platform may, until evidence to the contrary is obtained, be regarded as primary.

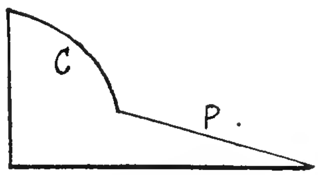

FIG. 1.—Diagrammatic section of a primary major platform.
P. Platform. C. Cliff.

In some instances a minor platform may be seen developing side by side (but each abutting the shore-line) with the major platform, this being due to the occurrence of different classes of rocks favouring one or the other type, as at Mt. Martha, Port Phillip Bay, Victoria (Jutson, 1940), where the minor platform is formed of decomposed granodiorite, whilst the major platform is of a fresh portion of the same rock.

(ii) SECONDARY PLATFORM. This platform follows a minor platform as the seaward edge of the latter retreats. In that case it is, at least where it abuts that edge, of secondary origin.

2. THE MINOR PLATFORMS

(i) 'OLD-HAT' TYPE. This is the form described by Bartrum (1926 and earlier paper therein cited). It is formed in a comparatively quiet sea from a rock which readily suffers atmospheric decomposition. The rocks weather down to the level of permanent saturation, which is a little below mean high-water level, and the waste products are removed by the weak waves of the sea. The present writer has not observed similar forms, nor does he know of any.

(ii) WAVE-EROSION TYPES. These are formed at varying heights above low-water mark by direct abrasion of the sea. (They may subsequently be modified by sub-aerial action.) They include the 'abnormal' or storm-wave platforms of Bartrum, with the limitation previously noted, the two upper platforms of Jardine (1925), the 'normal' platforms of the writer, the two-metre bench of Douglas Johnson, and, apparently, the storm-wave platforms of Edwards.

Two aspects of these platforms may be considered. First, the occurrence, on some shores, of two or more platforms rising one above another; and secondly, the influence of geological structure on the formation, shape, and extension or reduction of the platforms.

(a) *Two or more Platforms at Different Levels.* These rise one above another at varying heights in relation to mean sea-level or other adopted datum, the difference in height between the different platforms ranging from about one foot

to three feet or more according to the height at which the waves can cut under the then prevailing conditions on any given shore (Fig. 2). They may be formed simultaneously or, where the land has emerged from the sea, successively at fixed intervals. Where only two occur, they may be termed 'high-level' and 'low-level,' as the writer has done in his papers on the shore platforms of Flinders and Lorne, Victoria. (These *Proceedings*, Vol. 60, 61.) Where three platforms occur, they could be termed 'low- (or first) level,' 'mid- (or second) level,' and 'high- (or third) level,' and where there are more than three, other appropriate terms must be used, such as 'shelf' or 'ledge,' which terms the writer has applied to the narrow,

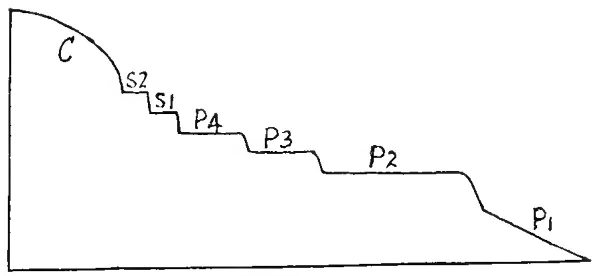

Fig. 2.—Diagrammatic section showing the various possible platforms and shelves. P1. Secondary major platform. P2. Low-level, first-level or basal minor platform. P3. Mid-level or second-level minor platform. P4. High-level or third-level minor platform. S1. and S2. Shelves. C. Cliff.

largely continuous horizontal projections from the cliffs at Flinders and Sydney (Jutson, 1939), where they were above two minor platforms. For similar features Edwards (1941) has used the term 'storm ledges.'

When the platforms are being cut simultaneously the lowest one is the main one, being usually much wider, longer and more continuous than that of those above it. This feature is well shown at Flinders, where, above a wide largely continuous platform, small isolated platforms occur. An alternative appropriate name for the main platform to 'low- (or first) level,' whether it occurs with or without another or other platforms above it, is 'basal.'

Some of the higher platforms are produced partly by the waves and partly by sea spray, a fact which has been noted by Edwards (1941) at Port Campbell and San Remo, both in Victoria.

(b) *Influence of Geological Structure.* The platforms may be separated into structural and non-structural ones, which is a useful division, since the rate of formation or destruction of a platform may be profoundly influenced by the geological structure of the rocks of which it is composed or out of which it has been carved. Similarly the smoothness or roughness of the surface of the platform may be influenced by geological structure.

Structural Platforms: A structural platform is one the surface of which corresponds with a structural division plane, and since the surfaces of the platforms are horizontal or sub-horizontal, that plane must be in the same position. Examples are, of course, horizontal or nearly horizontal sedimentary beds, or approximately horizontal alternating beds of lava flows and pyroclastic rocks.

The division planes facilitate the comparatively rapid removal of the rocks, and this would be intensified if, at about the level the platform was being cut, a bed of soft rock, e.g. shale, overlay a hard rock, e.g. sandstone. The shale would be

rapidly removed along the upper surface of the sandstone bed and that surface would become the shore platform. For examples, see Jutson (1939), p. 244; Edwards (1941), p. 235; and Hills (1940), p. 84. Moreover, according to the vertical position of the hard bed, the height of the platform would vary within certain limits.

A strong system of more or less horizontal joints in an igneous rock would help towards the formation of a structural platform, but it is doubtful whether the joints would be of sufficient regularity and vertical spacing to permit the production of a platform of any evenness of surface. The surface would indeed most probably be extremely irregular. A platform of that description would be intermediate in character between the typical structural and the typical non-structural platform.

Non-structural Platforms: Non-structural platforms may be divided into two classes—(a) sedimentary rocks, and pyroclastic rocks alternating with lava flows, all with a definite dip; and (b) massive igneous rocks, e.g., granites and basalts. In the first group the platform truncates the beds and in most instances would have a fairly even surface, although the harder beds would tend to project above the general surface. In the second group, owing to the prevalence of strong joints, the surface would be irregular, especially in the case of basalts with strongly marked columnar structure.

(iii) Spray-Erosion Type. Ongley (1940) has shown that the spray of waves is eroding, by differential weathering, platforms 55 feet to 80 feet above the sea. 'The beds fronting the sea strike parallel to the coast and dip inland.'

Bartrum in a personal communication to the writer states that he has seen a structural platform quite 100 feet above sea-level being eroded by spray, the beds removed from the bench being soft sandstones.

As noted by the writer (1939) near Sydney, spray alone is probably forming platforms (ledges or shelves) by the removal of shales which alternate with sandstones, the upper surface of the sandstones forming the tops of the ledges or shelves (p. 246).

All these examples illustrate structural control in the formation of the platforms.

It is difficult to conceive of spray-eroded platforms of a non-structural type, but it is interesting to note that Wentworth (1938) states that spray-erosion may have moved a large block of rock. Thus there is the possibility of a very irregular platform being formed of the non-structural type, but perhaps its surface would be so irregular as hardly to deserve the name of 'platform.'

All spray-erosion platforms are doubtless modified in a greater or less degree by atmospheric erosion.

(iv) Water-Levelling Type. This has been fully and first described by Wentworth (1938). Shortly stated, the mode of formation appears to be that on a pre-existing platform the surface is such that pools of water can collect, and that those parts of the platform which rise above the pools weather away owing to alternate wetting and drying, with the result that the surface tends to become more level. Wentworth considers that water-levelling can take place simultaneously at different levels. If that be so, and the levels are fairly well defined over comparatively large areas, then the terminology suggested for the wave-erosion types of the minor platform may be suitable.

(v) Solution Type. Wentworth (1939) has also shown that there are platforms in limestone which have been formed by the solution, chiefly by fresh water, of the limestone surface. Until more examples are known, no subdivision of this type will be attempted.

3. RAISED AND SUNKEN PLATFORMS

An objection may be offered to the classification above proposed on the ground that it takes no account of raised or sunken platforms. Platforms may of course be raised or sunk either tectonically, or by a eustatic fall or rise, as the case may be, of sea-level; and so they can be divided into raised, sunken, non-raised and non-sunken platforms. (The last two terms are used to avoid using the word 'stationary,' which would be misleading.)

Whether or not there has been a change in sea-level and so altered the relative positions of the platforms, the fundamental division into the major platforms and the minor ones remains. If there has been emergence or submergence, then the result of that action can be added as a qualifying term to the fundamental name, as, e.g., a raised minor platform.

Other distinctions will be necessary. Thus a raised major platform may become by erosion, in part, a minor platform. Similarly, a minor platform on submergence may by erosion become part of the major platform. In cases like these the required qualifying terms must be found.

Acknowledgment

The writer desires to place on record his great indebtedness to Professor J. A. Bartrum, of Auckland University College, Auckland, N.Z., who has been one of the pioneers in the modern study of shore platforms, for many valuable suggestions and for helpful criticism in connection with the subject matter of this paper.

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3

THE CYCLIC LAND-SURFACES OF AUSTRALIA

A GEOMORPHOLOGICAL SUMMARY

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Contents

Introduction

The recent establishment of geological ages for the various cyclic land-surfaces of Africa (King 1949), and the possibility that land-surfaces of comparable age and development might be found in other parts of the world, have prompted this enquiry into the landscape history of Australia.

Without recapitulating the arguments of the above-mentioned paper, and of others which preceded it (King, 1947, 1949a), we may state simply its essential conclusions, which will be fundamental to the present study:

(a) That on the continental scale erosion cycles operate to enlarge their dominion and destroy the relics of earlier cycles, not by the 'peneplanation' of W. M. Davis, involving down-weathering, but by the processes of scarp retreat and pedimentation (combined as *pediplanation*); so that fragments of earlier cycles may long survive in the landscape as plateaux, tablelands or bevelled hill-tops. The evidence for pediplanation as the mode of development of Australian landscape is overwhelming, especially in the centre and west, where the process has been clearly described at work by Jutson (1934, pp. 233-237), and in the eastern highlands, where Craft (1933, 1933a) has remarked how smoothly-planed landscapes at different levels are separated by steep erosional scarps.

(b) That the oldest of these tablelands are Mesozoic in age and correspond to the land-surface of the parent super-continent Gondwanaland; the cyclic surface succeeding this (the Great Australian Pediplain in Australia) was initiated on the break-up of Gondwanaland in the Cretaceous period and continued current at the coasts until the mid-Tertiary; while a third group of surfaces has been generated by intermittent continental uplifts in the late-Tertiary and Quaternary.

We repeat: the above conclusions, valid for Africa, are basic also in the scientific study of Australian scenery.

Australia: Ancestral

Within Gondwanaland, the position of Australia was surely peripheral. That it was distant from South Africa is indicated by the absence of Mesozoic rocks of

Karroo type. The continent of Antarctica, one and a half times the size of Australia, possibly stood between them.

The date of separation of Australia from the parent Gondwanaland may be fixed from Western Australia. In that state, rocks of Triassic age are absent, but marine Jurassic, Cretaceous and Tertiary formations occur marginally. According to the map issued (1933) by the Geological Survey of Western Australia, Cretaceous rocks are known only south of Shark Bay, a condition consonant with the opening of a rift from the north, and closely paralleled along the eastern coast of Africa.

We may conceive, in the ancestral Mesozoic Gondwanaland, of Western Australia as a vast plain only a few hundred feet above sea-level and descending to swamps at still lower altitude in the centre of the continent. On the site of the present eastern Australia rose the bevelled stumps of late Palaeozoic mountain chains. Australian geologists (David 1932, p. 87; Bryan 1944, p. 60) have insisted that the land extended eastward, far beyond the present coast, over what is now the Tasman Sea. If so, it must have been low-lying: any Tertiary marine rocks have disappeared by late-Tertiary subsidences.

Following the disruption of Gondwanaland, and with the early eastward travel of the newly-born Australia, the central lowland was flooded by early Cretaceous epeiric seas, and the Gondwana land-surface was there buried beneath arenaceous sediments shed from the in-tilted landscapes surrounding the basined focus. Perhaps Hudson Bay is the nearest modern approach to the type of scenery involved.

Gondwana Elements in the Present Landscape

The lapse of time since the Cretaceous period, when newer erosion cycles were initiated, is so vast that these cycles have been able to destroy the 'Gondwana' surface over almost the whole of Australia (excluding the central disc where that surface was basined and buried beneath Cretaceous sandstones). Such portions of the 'Gondwana' landscape as do survive are but tiny plateau remnants standing at scarps above the wide plains of the younger cycles. Despite possible minor modification, these must be regarded as having been cut originally by agencies operating in cycles that were graded to 'Gondwana' base-levels. (Fig. 1.)

The great age of the 'Gondwana' landscape, and the immense lapse of time that must have gone to its fashioning, are indicated by the vast area over which it is eroded across very ancient granitic and Archean rocks.

The small difference of elevation (*circa* 300 feet in Western Australia and 400+ feet in parts of New South Wales) between the 'Gondwana' and 'Australian' (q.v.) pediplains also argues (a) a peripheral position at low altitude for Australia in the Gondwanaland jigsaw (a conclusion fortified by the Cretaceous inundation of the east-central region, and the Tertiary marine encroachment of Euclonia in the south), and (b) a remoteness from the African segment of Gondwanaland where the difference between the two corresponding surfaces amounts to 2000 feet.

In Western Australia. This state affords one of the finest examples of a stable region to be encountered anywhere on the globe. There has been no folding of any consequence since the pre-Cambrian, while "the late Palaeozoic sediments of the Great Desert Basin are still so unconsolidated and porous as to be an important source of artesian water, and Palaeozoic coals there are still somewhat hydrous" (David 1932, p. 14). Geographically it has been a great plain since the late Palaeozoic, but undoubtedly the prolonged erosion responsible for laying bare many

of the ore-deposits, deep-seated in pre-Cambrian granitic and schistose rocks, was accomplished even before that date.

A valuable physiographic survey of the state has been rendered by Jutson (1934), whence have been derived many of the facts quoted hereafter.

The most extensive remnants of the 'Gondwana' land-surface survive in the north-west. North Kimberley is essentially a dissected erosional plateau, the numerous 'ranges' on the map being merely the unconsumed plateau ridges between the valleys of the incised streams. (Jutson 1934, pp. 34-46). The south-western face may be a fault scarp, but the eastern boundary is less definite and leads down by erosion scarps to the Ord Plateau, the local development of the great 'Australian' cycle of erosion. Many of the streams radiate from Mt. Hann, a monadnock 800 feet above the plateau at its base, which stands at 2000 feet above the sea. On the north and west there appears to be a monoclinal outwarp towards the coast, and the country is gashed by deep valleys with vertical cliffs of sandstone.

In Pilbaraland, Murchisonia and Swanland to the south, again there is a dissected plateau, surmounted by monadnocks and sometimes exceeding an altitude of 3000 feet. The silcrete-capped Collier Plateau stands between 2500 and 2750 feet and is one of many plateaux cut through by the canyons of rejuvenated rivers. The indifference of these river courses to the general trends of geological structure indicates either superposition from an unconformable cover (of which there is no evidence) or downcutting from a previous stage of planation so extreme that the rivers ceased to be influenced materially in their courses by the structure of the bedrock. Such a stage of planation is indicated on the 'Gondwana' remnants cut without discrimination across all the local formations. In Swanland, the remnants of the 'Gondwana' plateau are termed the Mount Dale Level. The relicts tend to become smaller and less numerous from the north of the state (North Kimberley) to south (Swanland).

Farther inland, the 'Gondwana' bevel appears upon the South Esk Tableland, 300 feet above the level of the surrounding (later) great 'Australian' pediplain; and thence, far south, the same bevel is continued upon groups of flat-topped hills and ridges, usually upon granite, but sometimes upon banded ironstones. The contrast in topography is enhanced by the lateritic hill-caps (aluminous, ferruginous or siliceous as the case may be) which demonstrate clearly the origin of the summit bevel as an erosional plain of extreme age and development. The difference of elevation between the 'Gondwana' and 'Australian' surfaces is 30-100 feet, though occasionally 200 feet. This is markedly less than in the north-west, indicating a convergence of the two surfaces, leading to a crossing in the east.

In South and Central Australia. With the exception, possibly, of Arnhem Land, the 'Gondwana' surface is seldom revealed as such in South Australia and the Northern Territory because, on crossing these states towards the east, it sinks to approximately the level of the 'Australian' surface in order that it may descend yet further, and form the floor for the Cretaceous sediments of the Great Artesian Basin. Thus in the zone of crossing any features that may belong perhaps to the 'Gondwana' cycle become merged with, and indistinguishable from, those of the later 'Australian' cycle. The Burt and Missionary Plains adjacent to the Macdonnell Ranges are thus feasibly of composite origin.

Notwithstanding, the transverse drainage system of the Macdonnell Ranges itself predicates a former summit level of some sort, either normal or upwarped 'Gondwana,' and it is important to search for any fragments of earlier erosion bevels which may survive thereon. Of special interest, therefore, is Madigan's

record (1931, p. 423) of "rough, rugged gneissic country which appears flat from the air" between the Heavytree and Chewings Ranges, and of a similar area five to ten miles wide north of the Chewings Range, where there is a steep fall to the Burt Plains. Photographs of the James Range to the south also favour an earlier ('Gondwana') planation of the crest there. No earlier bevels have been recorded from the Musgrave Ranges though Mt. Woodruffe, the highest point in the state, rises to nearly 5200 feet. Perhaps we are dealing here with a locally upwarped portion of the 'Gondwana' surface, renewed, perhaps, on the site of a still more ancient warp—a suggestion which would account also for the unusual height of some of the ranges (2000 feet) above the plain.

The 'Gondwana' bevel may, of course, locally be exposed as a resurrected surface by stripping of once-overlying Cretaceous sediments, but examples do not seem to have been quoted in literature.

In Victoria. Victoria is well documented and the physiographic evidence has been ably handled by Hills (1934, 1940). Four cyclic phases or groups have been made out, the earliest of which (Cretaceous) corresponds to our 'Gondwana' cycle.

The relicts of a once-planed 'Gondwana' surface survive upon resistant Devonian lavas of the Warburton-Healesville-Marysville district, as a high prolongation from the main divide south-eastwards towards Mt. Baw Baw. Mt. Buffalo and the Bogong High Plains represent the same cycle farther to the east upon other resistant rock masses. These districts are extensively dissected in the succeeding 'Australian' cycle which, according to Hills' diagrams, is developing by the processes of pediplanation. The elevation of the plateaux is from 3500 to nearly 6000 feet, indicating differential uplift during their subsequent history.

The Cretaceous age assigned to the bevels by Hills is derived from the observation that the former plains had been extensively dissected in the 'Australian' cycle before the eruption of the Older Basaltic Lavas which lie at Berwick, Narracan and Pascoe Vale upon pipe clays of Oligocene age. The age so derived is consonant with that of the similar small plateau remnants in similar situations relative to the great 'Australian' pediplain in other states. There is, however, some question whether two distinct phases of the Older Basalt may not exist.

Doubtless, at the time of subsidence in the interior to receive the Cretaceous marine sediments, the Victorian divide formed the south-eastern rim of the basin.

In New South Wales. Excepting a moiety in the south-west, New South Wales has not been beneath the sea since Mesozoic times and the present topography has been developing since the Cretaceous at least. There has thus been ample time for planation, and plains are widespread, often converted into tablelands by circumdenudation in much later cycles of erosion. The country should be ideally suited to the mapping of cyclic erosion surfaces, though there is some doubt as to the extent of tectonically induced relief in some localities (Cotton 1949, p. 280).

Small tableland fragments in the landscape of New South Wales have been ascribed by Süssmilch (1937) to a Cretaceous peneplain which suffered a late- or epi-Cretaceous uplift and was subsequently dissected by a new cycle (the 'Australian') which also attained extreme planation. These fragments are thus comparable with the residuals of 'Gondwana' landscape which surmount the main divide of Victoria, and may be assigned to the same ancient cycle of erosion. Examples are: towards the Queensland border, the tableland standing at 4000 feet, above the later plain of the 'Australian' cycle at 3000 feet; in the centre, the higher parts of the Blue Mountain Tableland; and in the south the 'pre-Tertiary' plateau at 4000 feet or so about the sources of the Murrumbidgee River (Craft 1933, pp.

230, 236). Some of the higher bevels and terraces may be due to earlier phases of the 'Gondwana' cycle, or to local upwarps of the region during the currency of the main 'Gondwana' cycle of erosion (King 1949, fig. 1).

In the north the 'Gondwana' surface stands locally at 400 to 1500 feet above the great 'Australian' pediplain, an intervening tilt to the west being shown by this variation.

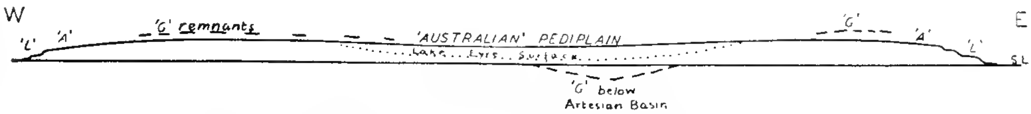

FIG. 1.—Diagram to illustrate the relationship of surfaces suggested in text. 'G' = 'Gondwanaland.' 'L' = 'Lake Eyre' and other later cycles.

In Queensland. In parts of the Great Dividing Range the 'Gondwana' surface has been exhumed locally from beneath the Cretaceous cover. It transects early Mesozoic terrestrial strata, the exposed ends of which form the intakes for the Great Artesian Basin. Yet this resurrected landscape is nowhere prominent, and most has been destroyed in the 'Australian' cycle which has cut flatly across it.

Elsewhere, the 'Gondwana' land-surface is not expressed topographically, though Whitehouse (1941, p. 1) notes it in the fossil state: "Unconformably upon the Mesozoic surface are early Cainozoic beds in the south-west and occasional remnants of late Cainozoic beds in the east."

The 'Australian' Pediplain

All the states of the Commonwealth display abundantly wide, rolling plains, frequently capped with ferruginous or siliceous "duricrust" (Woolnough 1927, pp. 17-53). Many of these are portions of a formerly even more widespread continental surface which we shall call the 'Australian' pediplain. Its appearance in the Eocene has been described by David (1932, p. 172): "We see that almost the whole of the Commonwealth has been reduced to one of the most perfect peneplains imaginable. . . . Only perhaps along the central and southern coastal belt of Queensland, where Laramie movement had been intense, and possibly in the sill-displaced blocks of Tasmania, have any elevations escaped base-levelling."

The 'Australian' cycle of planation made its *début* with the fracturing of Gondwanaland and the assumption, by Australia, of independent continental status. New base-levels were created, in part by monoclinal downwarping of the margins (e.g. Western Australia), and in part by regional subsidence with peripheral tilting (e.g. Central Australia). On the whole the difference of elevation between existing 'Gondwana' and 'Australian' surfaces is small.

All available evidence insists that the mode of development of the 'Australian' land-surface was by river incision, scarp retreat and pedimentation; except in the central disc, where it was originally largely aggradational. So effectively have the pediplanational processes operated that, as we have seen, only a few minor relicts of the earlier 'Gondwana' land-surface survive in the great breadth of the Australian continent; and though the 'Australian' pediplain has itself been attacked by later cycles of erosion, it is still more widespread than any other.

The period during which the 'Australian' cycle was current at the coast extended from the Cretaceous to the Oligocene or Miocene, so that in its mode of develop-

ment, relative distribution and age limits it corresponds to the 'African,' 'Indian' and 'South American' land-surfaces described elsewhere (King 1950).

In Western Australia. The vast plateau forming almost the whole of the state stands approximately 1500 feet above the sea, and is encompassed upon three sides by relatively narrow coastal plains. Upon the fourth (eastern) side it continues without significant alteration, though at slightly lower elevations, into Central and South Australia.

Over the whole of this vast territory the mode of development has been by scarp retreat and pedimentation, and the few residual hills which rise from the general surface do so abruptly at erosional scarps. Such are the only eminences apart from possibly a few fault blocks (Stirling Range) (Jutson 1934, p. 6). Certain of the residuals bear the summit bevels of the 'Gondwana' cycle standing from 30 to 300 feet above the level of the 'Australian' pediplain.

Much of the general elevation of 1200 to 1500 feet achieved by the Western Australian plateau must be ascribed to uplift in Tertiary time (*q.v.*). Slight irregularity of uplift, like the warp extending from Victoria to the Nullarbor Plains, may have been responsible for the subdivision of the plateau into areas of exterior drainage, and interior drainage into different centra. The alluvial plains of some of the rivers of the interior may also be due as much to back-tilting as to the local abundance of waste.

The Ord and Fitzroy river basins exhibit the main or 'Australian' pediplain, lower than the 'Gondwana' surface of North Kimberley and Pilbara. Northwards, the relations between them have been complicated by local upwarpings of both surfaces. Southwards, the pediplain becomes progressively more widespread at the expense of the earlier bevel, until it forms the whole of the wide, arid expanse typical of the inland scenery of the state. There are no true rivers in the far interior, for the rainfall is often less than ten inches per annum. Vertical corrasion is thus at a minimum and, apart from the sand country, surface accumulations of detritus are few. Even the lateritic duricrust is relatively thin.

The surface descends irregularly eastwards and south-eastwards, between altitudes of 1000 and 2000 feet. Slopes are generally between two and five feet per mile. To the eastward and north-eastward the pediplain is partly masked by accumulations of sand.

In the extreme south-east (Jutson 1934, p. 127) is the Nullarbor or Eucla region, of almost horizontally-disposed Miocene marine limestones. From the coastal cliffs (200 to 400 feet) the limestones rise slowly inland to 1000 feet, with 450 to 650 feet of the Trans-Continental Railway. The plain is almost incredibly flat, and the railway runs for 330 miles without a single curve. This flatness, combined with the marine types of sediment involved, suggests that the surface may follow the original depositional form despite later sub-aerial erosion. The limestone is cavernous and the region is without flowing rivers, so that sub-aerial erosion has, in the dry climate, been at a minimum.

Little is known of the relation between the limestone surface and the 'Australian' pediplain, for the region is inhospitable and difficult of access. Moreover, it would be exceedingly difficult to decide without extensive survey whether is involved (a) a single erosional surface ('Australian') bevelling older rocks and Tertiaries alike, (b) two surfaces: the 'Australian' pediplain continuing below the limestones and a newer surface, either depositional or erosional, forming the limestone plain, or (c) an earlier phase of the 'Australian' cycle passing below the limestones while a later phase of the same ('Australian') cycle cuts across them above, after elevation.

Presumably the angle between the two cyclic, or two sub-cyclic, surfaces would be so small as to be difficult of measurement in the field. For the present, while retaining all three of the above working hypotheses, we may regard the second as most feasible, with the sub-limestone surface as an early phase of the 'Australian' cycle and the supra-limestone surface a *depositional* equivalent of a 'late-Australian' phase on the continuously exposed land to the north.

In South and Central Australia. The exceptional hilly tracts within the state are limited to the ancient, dissected strike-ridges of the Macdonnell and Musgrave Ranges in the heart of the continent, and the Flinders and Mt. Lofty Ranges, a series of horsts, in the south. The rest of the region consists of plains, in which two levels are prominent, one above and one below 500 feet. The upper is the 'Australian' surface which enters without alteration across crystalline terrains from Western Australia. These plains slope gently eastward and south-eastward until they are encroached upon at low scarps by a younger ('Lake Eyre') cycle. The 'Australian' cycle passes also across the Cretaceous rocks of the Great Artesian Basin; but here a younger cycle is dominant and the 'Australian' pediplain, heavily lateritized, truncates the flat-topped 'tent hills' which rise sharply from the younger plain.

Thus the 'Australian' pediplain here constitutes a plateau and links up with a similar plateau forming the southern part of the Northern Territory, and extending to north and south of the Macdonnell Ranges as the Burt and Missionary Plains. Little information is available regarding the topography of this territory, but away to the north the 'Australian' pediplain makes the striking summit bevel of the Barkly Tableland (Whitehouse 1940a), on which feature it is carried into western Queensland.

Photographs reveal that the Musgrave and Everard Ranges of South Australia rise as inselbergs from smooth pediments in a manner that betrays unmistakably their origin under a cycle of pediplanation involving scarp retreat. The ranges are low and scattered and are typical inselberg monadnocks in a vastly eroded landscape. Wind has been claimed as their chief eroding agent, but even allowing for some change of climate during the long period of their existence, the drainage systems and forms of the hills and of the pedimented plains reveal the dominant operation of sheet water-flow. Only in the great sand deserts to the north-east and north-west does wind hold the upper hand in landscape development.

Characteristic upon the 'Australian' pediplain, in South Australia as elsewhere, is the 'duricrust' or lateritic covering. It is best seen, perhaps, where much of the surface has been destroyed in younger erosion cycles and the pediplain is left truncating innumerable residual hills, the mesa-like appearance of which is enhanced considerably by the hard, accordant caps of silcrete or laterite (e.g. near Oodnadatta). The age of the Australian laterite, as far as can be judged from associated fossils, ranges from Cretaceous to Pliocene (cf. Africa (King 1949)), and there has, locally at least, certainly been more than a single period of formation (Whitehouse 1941, p. 5). From analogy with similar deposits in Africa we may accept that the deposits have been formed semi-continuously over a great lapse of time rather than in brief, intense periods of greater rainfall. As stated elsewhere, time and seasonal drought, rather than pluviation, seem to be the keys to the formation of laterite and its siliceous, ferruginous and calcareous congeners. Where the lateritic armour of the pediplain has been fragmented, a rubble of intractable 'gibbers' lies strewn across the surface.

The duricrust is important, for it indicates that the 'Australian' surface has possibly survived through several geologic periods without significant lowering under erosion. There is, indeed, little reason why undisturbed land-surfaces which have once attained an advanced stage of planation should be materially lowered however long they are exposed to the elements.

If, as is believed, the 'Australian' cycle was initiated as early as the beginning of the Cretaceous period, it was doubtless well advanced before that period closed. Doubtless, also, the lacustrine, estuarine and marine Cretaceous sediments of the continental interior were derived as the debris shed from the surrounding, differentially elevated country under the earlier, vigorous phases of the cycle. Following the disappearance of the inundations, the later phases of the 'Australian' cycle were extended, in the interior, over the sediments the earlier phases had supplied. The changes effected would probably be slight; and the aspect of certain of the great plains, where they have not been attacked by younger cycles, may not differ markedly from the original depositional aspect of the late Cretaceous. Herein is a useful principle: if erosional surfaces can, and do, survive almost indefinitely under favourable conditions, why should not depositional surfaces survive also?

The Gawler Ranges, south of Lake Gairdner, are an assemblage of residuals upon the 'Australian' pediplain. As such, they owe their existence in parts to the superior durability of the pre-Cambrian felspar porphyries of which they are composed. They are, naturally, ancient, and some evidence of Cretaceous glaciation has been forthcoming from this locality, perhaps incurred as Australia in its drift from Gondwanaland passed its southern nadir on a great circle course (King 1944, p. 8). But the modern ranges are regarded as due also to an upwarp, probably late Miocene in age, co-linear with the Peterborough Plateau and the Olary Ridge to the east. The latter of these is a broad, upwarped plateau (1000-2000 feet) with the great rolling surface of the 'Australian' cycle of erosion. Stream courses upon it are often (according to Howchin) "uncertain and anomalous, and may change direction from one flood time to another."

In Victoria. Under other titles, the 'Australian' pediplain has been identified in Victoria by many authors. Near the divide, where the 'Gondwana' relicts still survive, there has been described an ancient topography of hills and valleys which represents an upland phase of the 'Australian' cycle. Towards the south, and presumably to the interior, there was much flat land. Thus, when the Older Basalts were poured out, converting the gravels of the stream-beds into deep leads, they were confined to the valley-floors up country, but spread much more widely as sheets on the lower country (Hills 1934, pp. 161-2).

Much of the 'Australian' surface of Victoria has been lost to later cycles of erosion, or has descended under tectonic influences to low level where it has been blanketed by marine or paludal formations (*q.v.*). Nevertheless, it was upon the 'Australian' surface in late Cretaceous or Early Tertiary time that the main divides and stream courses of the state were first established, following differential movements in the Murray Basin to the north and Bass Strait to the south. (Hills 1940, p. 271.)

In New South Wales. The dissection of the 'Gondwana' surface, begun in the late Cretaceous, culminated, according to Süssmilch, in the Miocene with the usual broad planation of the 'Australian' cycle across New South Wales. In the north-west and south-west of the state wide tablelands still carry the hallmark of this cycle in their summit plains; but the best undissected areas are probably those adjacent to the Great Divide (Süssmilch 1937, p. xxvii). Thus at Emmaville,

towards the Queensland border, the surface stands at about 2900 feet on granites and porphyries. It possessed valleys some 300 feet deep in which deep leads and plant-bearing beds of Eocene age* are preserved below basalts equivalent in age to the Older Basalts of Victoria. Tilting north-eastward shows in the attitude of the surface, which descends from 3000 feet at Hargreaves to 2000 feet at Wellington and 1500 feet at Dubbo. The main tableland surface of the Blue Mountains belongs to the 'Australian' cycle, and in the south the Monaro plain at 3000-3300 feet (Craft 1933, p. 232). The surface, indeed, slopes west through much of the state, presumably by later dishing of the centre of the continent.

Other differential movements accompanying the development of the Murravian Gulf ended the 'Australian' cycle there by drowning it below sea-level. The same movement no doubt altered the courses of many of the rivers, e.g. Darling (David 1932, p. 89).

In Queensland. Western Queensland was covered by Cretaceous seas and swamps, and the accumulations of that far-off geography are still almost horizontally disposed. In the absence of any marked deformation the 'Australian' pediplain has thus had full opportunity for development. It is admirably displayed upon the so-called Great Dividing Range, which is essentially a zone of the pediplain so gently upwarped that a number of basins of centripetal drainage occur even at the crest of the Divide itself. It is encroached upon by younger cycles operating up the shorter streams of the eastern coast, but occasional tablelands still survive on the interfluves (e.g. Mt. Morgan Tableland). Süssmilch (1928, pp. 128-129) has explained the scarps bounding the tablelands as due to faulting. Without traversing his arguments, we may prefer to interpret his data in the light of the pediplanation cycle operating to newer base-levels, and find only the usual retreating scarps of younger erosion cycles cutting with relative indifference across various rock series, after being generated in conformity with a drainage pattern partly controlled by geologic structure.

As elsewhere, the pediplain is veneered with laterite ('duricrust') and residuals of this veneer surmount the very divide. Clearly, when the laterite accumulated, the divide was not in existence. On the Alice Tableland the laterite sheet, virtually unbroken, covers an area of over 20,000 square miles, and illustrates very clearly the pristine condition of the pediplain. Local opinion has tentatively regarded the laterites as Pliocene in age (Whitehouse 1940, p. 17) ; but there seems no reason why the bulk of the deposit should not be vastly older as is the case on corresponding land-surfaces in other continents (King 1949). In favour of this interpretation is the fact that basalts poured out at the crest of the divide are younger than the laterite and yet have been dissected; and also the vast destruction of the laterite cover carried out by younger cycles in the west, and the erosion of the pediplain accomplished by the rivers of the eastern slope. The youngest rocks transected by the pediplain are those of the early Tertiary Eyrian Series in south-west Queensland.

From the divide, the 'Australian' pediplain slopes gently westward until it is dissected by the valleys and plains belonging to younger erosion cycles. There is a wide area in the basins of the Georgina, Thompson and Cooper Rivers over which the dissected pediplain appears as innumerable accordant mesas, each bearing the appropriate cap of laterite, e.g. Boulia. Often nothing is left but a scattering of

*Attention should be drawn to Süssmilch's discussion of the value of fossil leaves for determining the ages of Australian Tertiary beds. Apparently, accurate dating is not possible by this means.

'gibbers' upon a few divides, and the vast 'Downs' and older alluvial plains of western Queensland have been developed by the destruction of the earlier 'Australian' pediplain. On the Barkly Tableland at the western borders of the state the 'Australian' cycle, cut on ancient limestones, passes out of the state.

Many of the drainage patterns originated upon the pediplain of the 'Australian' cycle, and the Warrego drainage to the Darling has been quoted as an example of this. Some of the gorges of the Gregory River through strike-ridges of pre-Cambrian rocks, and certain reaches of the Leichhardt, also probably originated by incision from the former 'Australian' land-surface, though no trace of laterite remains locally to point its former presence.

Seldom does any marked topographic feature separate the interior drainage from that external to the Gulf of Carpentaria. The headwaters of the Diamantina are separated from the gullies of the northern drainage only by a plain a mile or two wide. Here again gentle warping has probably initiated the divide, though southward migration under headward erosion has also doubtless played a part.

The 'Lake Eyre' and Other Later Cycles

The 'Great Australian Pediplain' provides the fundamental topographic datum for the Commonwealth, but over much of the continent it has been destroyed during subsequent erosion cycles, and is succeeded by younger suites of landforms. These cycles have been initiated principally by continental uplifts and deformations, the first of which seems to have been of late Oligocene or Miocene date. The uplifts were not uniform, and differential and opposed movements are often shown at the coasts.

There is naturally a greater range of local variation between the facets of these later cycles which would be fascinating to work out in detail. But this we must for the present eschew, and the various cycles of Miocene or post-Miocene initiation will be treated collectively.

We must pause, however, to note an important feature of these cycles. The drainage of more than half Australia is endoreic. Topographic features over this vast area will thus be developed independently of true oceanic base-level, but instead with reference to a host of local base-levels of great or of little importance. The chief of these is the base-level provided by Lake Eyre and we shall refer to the most important group of the post-Australian cycles, succeeding the 'Australian' cycle itself, as the 'Lake Eyre' cycle, recognizing, however, that it is not single but multiphase.

In Western Australia. The altitude of the 'Australian' pediplain (1200-1500 feet) betokens a subsequent elevation of nearly a thousand feet in late Tertiary time. This estimate is supported by the record of Marine Tertiary (Miocene) rocks standing 900 to 1000 feet above the sea at Norseman, near Lake Cowan, 120 to 150 miles from the present coast. In the Eucla Basin, too, marine Tertiaries rise to nearly 1000 feet at their inner edge. Oligocene marine sediments also rise to 1000 feet above the sea west of Exmouth Gulf; but here much of the uplift is local, for the structure is anticlinal.

The uplift of Western Australia was not uniform. Jutson (1934, p. 203) records: "The plateau on uplift would appear to have had a vast undulating surface due to a series of very gentle folds or warps, broken occasionally by fault-scarps." He refers also to great flat domes in Pilbaraland and North Kimberley.

The divide separating the oceanic from the interior drainage is also feasibly a result of uneven uplift of the 'Australian' pediplain. The descent to the coast is gradual in Murchisonia but southward takes place suddenly at the Darling scarp, below which marine Cretaceous beds appear at intervals (500 feet altitude at Gingin). Of this scarp, Dr. D. W. Johnson has expressed the opinion that it may have developed from a monoclinal fold of the coastal zone, with differential erosion upon rocks of different degrees of resistance. Prider (1945) also regards it as a scarp due to differential erosion.

But the best evidence of intermittent uplift comes from the carving of 'partial bevels' at elevations between that of the 'Australian' pediplain and features due to the present cycle of erosion. Best known of these is the 'Meckering Level' at 800 feet along valleys incised into the Darling Plateau ('Australian' cycle) of the west; and there are also erosional terraces at 450 feet and 250 feet respectively above the sea. Woolnough has assumed erosion in the Meckering Level cycle to have been contemporaneous with the Norseman limestone. No close correlation has been made between the stages of uplift in the Eucla region and the other, lower, bevels of the western coast.

In the interior of Western Australia the 'Australian' pediplain has been but little dissected by later cycles.

In South Australia. The second existing planed surface of central and southern Australia stands at lower elevation, and is younger than the 'Australian' pediplain. This later cycle has been induced partly by continental uplift and partly by the sinking of interior basins, of which the Lake Eyre basin is the largest. That sinking was actual, and not merely relative, is proved by the depression of Lake Eyre which is itself below sea-level, though recent marine formations do not appear anywhere within the basin.

Events post-dating the main development of the 'Australian' pediplain may thus for convenience be studied under two heads, accordingly as they affected regions of endoreic drainage, or of exoreic drainage.

During the early Tertiary era, great rivers flowed southward through Central and South Australia; then, probably in Miocene time, two profound, though gentle, movements combined to sever these courses before they reached the sea. The first was the immense downsagging of Lake Eyre and the second was an arching along an east-west line, of the Gawler-Peterborough-Olary upwarp which locked in on its northern side Lakes Gairdner, Torrens (in part also a sunken graben) and Frome (Fenner 1931, p. 26). Thus most South Australian rivers now terminate not at the sea, but in huge, alluviated depressions, which themselves form some of the most significant features of the geography of the state.

The Lake Eyre basin, in particular, functioned as a new base-level, and congruent cycles of erosion have operated to destroy the great 'Australian' pediplain over a vast proportion of the interior. The new plains, mainly erosional but in part depositional, make the most widespread landscape in South Australia. The surface has been partly silicified, as at the opal fields of Coober Pedy. Remnants of the earlier 'Australian' surface often form accordant, flat-topped, steep-sided 'tent-hills' or mesas, capped with silcrete, as in the same locality (Fenner 1931, p. 29), and serve to demonstrate the pediplaned origin of the later, or 'Lake Eyre,' cyclic land-surface. The highest of the 'tent-hills' stand about 200 feet above the lower plain, as near the boundary with the Northern Territory (Madigan 1936, p. 63).

Across the landscape of the 'Lake Eyre' cycle, the rivers, loaded with debris and adapted to carry rare floods, make the frequently braided and reticulate patterns

(Cooper, Diamantina) which Madigan (1936, p. 139) has described as so typical a feature of Central Australia: "Though mighty rivers begin their long journey to Lake Eyre from 600 miles away, yet their courses are indefinite in South Australia for hundreds of miles and they have countless swamps and minor lakes to fill before their waters can reach Lake Eyre. The country north-east from Lake Eyre for 250 miles, to the Queensland and New South Wales borders, is a great alluvial plain, really the inland deltas of the Diamantina and Cooper." In some districts are also long parallel sand-dunes.

Lake Eyre is the focus of this vast inland drainage system. The land-surface of the 'Lake Eyre' cycle is thus largely depositional, but the deposition follows an earlier phase in which erosion destroyed the greater part of the earlier 'Australian' pediplain. Without question, the 'Lake Eyre' cycle is multiple, and erosional and depositional phases have alternated over a long period; but insufficient data are available to distinguish the individual phases yet with any degree of clarity.

South of the Gawler-Olary warp, and continuous with the Nullarbor region (Euclonia) on the west, is the Mallee, a region of plains composed of Miocene marine strata. Credibly the sinking of the Mallee was contemporaneous with the sagging of the Lake Eyre basin: a correlation which suggests a mid-Tertiary date for the initiation of the 'Lake Eyre' cycle in the interior. Certainly this accords well with the vast amount of erosion accomplished, in an arid to semi-arid environment, by the 'Lake Eyre' cycle, and the fact that the cycle transects locally in the interior early, but not late, Tertiary strata.

There was possibly some tilting southwards of Australia as a whole about the same date (Miocene) which, be it noted, approximates also the period of folding of the great ranges of New Guinea (Burdigalian). Be these matters as they may, we observe that by the end of the Oligocene the 'Australian' surface had attained extreme planation, and by the Miocene had sunk to the south in a broad Euclonian-Murravian Bight extending far into Victoria (Hills 1940, fig. 349).

After an interesting interval in which brown coals (Yallournian) were deposited (Mawson 1936, p. lxii), three hundred or more feet of limestone accumulated in this bight before the region rose gently again in the earliest Pliocene. The upper, depositional surface of the limestone formed the primitive state of the broad plains of the present-day Mallee. In places the limestones have since been wholly stripped to reveal the fossil surface of the 'Australian' pediplain cut across the crystalline pre-Cambrian undermass.

Irregularity of uplift, and perhaps later Kosciusko movements, formed shallow basins, now largely filled with alluvium and sands (Fenner 1931, p. 59).

The structurally similar plains south of the Mallee show a post-limestone (?Kosciusko) faulting parallel to the coast, and the region is one of slow, intermittent rise with former coastal dune ridges parallel to the existing Coorong (Fenner 1931, p. 59).

Westward, the Mallee passes into the comparable level treeless expanse of the Nullarbor limestone plains, in this state reaching to 500 or 600 feet above sea-level. This, as we have noted, may well be a surface of deposition, innocent of sub-aerial planation since its emergence on account of the prevailing extreme aridity and the porous nature of the limestone bedrock.

On the opposite side of the continent, in the Northern Territory, a post-'Australian' cycle again appears. Thus, north of the Macdonnell Ranges, the Burt Plains ('Australian' cycle) stretch as far as Hann's Ridge and Ryan's Well (Madigan 1936, p. 99), where the country becomes rougher under dissection by a

new cycle. The country around Central Mt. Stuart is again like the Burt Plains, but thirty miles beyond the country is once more dissected. Near Barrow Creek, flat-topped hills of rotten granite, capped with duricrust, rise to the level of the 'Australian' pediplain with considerable resemblance to the topography of the Lake Eyre basin.

Thus a new cycle is hereabouts plainly etching its way into the great 'Australian' pediplain. As none of the drainage of this region is tributary to the sea, but broad basins exist, the new cycle may well have been induced by local downwarps such as the well-known Polygonum Swamp. The cycle may provisionally be correlated with the 'Lake Eyre' cycle.

In the small drainage systems of the north, tributary to the Timor and Arafura Seas, a cycle younger than the 'Australian' is again apparent, as north of the Barkly Tableland.

The Kosciusko block-faulting finds expression within the state in the Mt. Lofty and Flinders Ranges and the adjacent Yorke Peninsula, and the sunklands of Spencer and St. Vincent Gulfs. The total movement on the faults is of the order of 3000 feet. Remnants of the Miocene marine limestone remain upon several of the lower blocks: Port Willunga, Port Noarlunga, Myponga on the Para block behind Adelaide, and at a height of nearly a thousand feet at the head of the Hindmarsh River and near Mt. Mary. From the higher blocks the marine cover has been stripped under erosion revealing a smooth crestline of the resurrected 'Australian' cycle, modified to some extent by mid-Tertiary wave-erosion. From the general level, Mt. Lofty (2334 feet) and other higher points rise as residuals. Certain of the intermediate blocks, such as the Sturt Block and Belair Block, also bear the stripped 'Australian' surface and serve delightfully in the interpretation of the scenic evolution of the ranges.

There is consistent evidence of a period of local planation following the first Kosciusko movements and prior to the last Kosciusko movements (Fenner 1931, pp. 43-48). Some of the summit bevels can, in that case, be assigned to this "anteconsequent" planation, and certain of the drainage features be better understood thereby; but nothing in this hypothesis conflicts with the major plan of continental landscape evolution as we have envisaged it to be. It is a complication wholly expectable in a region marked by strong late-Tertiary differential movements. Other drainage changes, perhaps allied, have been described by David (1932, p. 91).

The Flinders Ranges are the northward continuation of the Mt. Lofty Ranges, yet they differ scenically because of the more arid environment which renders them bare and inhospitable. The ranges continue northward until they finally plunge below the sediments of the great interior basins.

In Victoria. Southern Victoria experienced the same Miocene-early Pliocene depression of the 'Australian' pediplain that affected the whole of the southern coast of Western and South Australia and formed the Murravian Gulf. As in South Australia, brown-coal swamps appeared in Gippsland (the Yallournian brown coal is 500 feet thick (Singleton 1939, p. 49)), and were succeeded by a full marine incursion extending to the southern flanks of the Central Highlands. Only the South Gippsland Highlands, Wilson's Promontory, the Mornington Peninsula and the Otway Ranges projected as islands above this shallow sea.

At least one local, partial surface, the Nillumbik Plateau, was carved at this time. Of this, Hills writes: "It is clear, however, from the fact that the Older Basalt residuals were left on the erosion surface, that no widespread erosional plain

was produced. The Nillumbik Peneplain is best regarded as a modified pre-Older Basaltic Terrain ['Australian cycle'] . . . of low relief." It is now revealed as a stripped fossil plain where the overlying Tertiary sands have been removed.

General uplift, accompanied by local warpings, supervened at the close of the early Pliocene (post-Kalimnan). The sea retreated and most of Victoria was re-exposed to sub-aerial erosion, at a somewhat lower level than the present. The fluviatile and marine sands of the Middle Tertiary were then carved, with the older terrain, into a matureland. The valleys were later overlaid by outpourings of Newer Basalt (Pliocene) which may be seen around Melbourne. In the western districts (Colac) wide lava plains spread across the country, the outposts of volcanic activity extending even into South Australia.

In the interior the sea had vacated the Murravian Gulf, since when much of the region (Mallee) has been traversed by late-Pliocene and Recent sand-dunes. No streams rise in the Victorian Mallee, and were it not for the great size of the Murray River and certain of its tributaries which rise in more humid regions, there would doubtless be no outflow at all from this region. Erosion by running water has thus produced relatively little modification of the original late Tertiary depositional plain.

South and west of the Mallee, the extensive alluvia (in places 200 feet thick) of the Wimmera overlie the slightly-dissected marine deposits of the Murray Gulf. Fluviatile effects have been aggradational rather than degradational.

Apart from minor touches, mainly along the coast, the configuration of Victoria was completed in the Kosciusko orogeny, when the final elevation of the Central Highlands was accomplished, with tilting of the torrent gravels upon their flanks; the block-faulting and doming of the Southern Highlands arrived at their present status; and finally the sea retreated from the Murravian Gulf.

For Quaternary time it is only necessary to record erosion of the upwarped and upthrown blocks, the drowning of Bass Strait with the formation of Port Phillip and the Gippsland Lakes, and the accumulation of extensive coastal dunes.

In New South Wales. The dating of Tertiary tectonic events is rendered difficult by the virtual absence of marine Tertiary strata from the state. Even the plant fossils seem to be of limited value for correlation (see previous note).

But the tablelands of the 'Australian' cycle are succeeded by a later, multiple, tilt-induced ('Lake Eyre') planation west of the main divide, and by a number of later cyclic episodes in the east (Craft 1933a). The Yass-Canberra Plain at 2000 feet, which is possibly an example of this planation, bears in its upper valleys flows of Newer Basalt. Deep-leads attest the remote age of many of the valley incisions. Süssmilch (1937, pp. xii, xvii) has regarded all the deep-leads as of the same age, but this view is perhaps due for revision. Certainly, the frequency with which deep-leads, or rather valleys 200-400 feet deep, occur in the planed landscapes of New South Wales suggests gentle tilting, probably repeated, to the west.

Deep-leads of late date occur upon the tableland at Gulgong, which stands at only 1600 feet above sea-level. Floras from the deep-lead beds have been identified as of Pliocene age. Still younger cycles are shown by valley-in-valley forms south of Wellington. Maze (1944) has drawn attention to downstepping erosional benches west of the Blue Mountains. Here is an example of multiple erosional bevels cut under a single continental cycle of erosion with repeated local uplift in the Blue Mountain region. (See King 1949, fig. 1.) Both the 'Australian' and

'Lake Eyre' cycles have been deformed in this manner west of the main divide with considerable modification of drainage systems.

The frequency of valley-in-valley forms in the landscapes of the coastal hinterland attests the episodic nature of the Kosciusko orogeny. At Mt. Kosciusko the 'Australian' pediplain was differentially elevated to 7000 feet, and at the Blue Mountains and New England Ranges to 3000-4000 feet, whence it continues into Queensland.

One may anticipate that mapping of erosional facets in the landscape of New South Wales will have more than usual interest.

In Queensland. The existing plains of western Queensland stand generally at a lower level than that of the laterite-capped 'Australian' pediplain. They may be ascribed to the earliest phase of the 'Lake Eyre' cycle, having been derived from the earlier cyclic plain, as descriptions plainly show, by scarp retreat and pedimentation following stream incision.

In the region tributary to the Gulf of Carpentaria the laterite-capped pediplain has been almost wholly destroyed, and so smooth is the 'Lake Eyre' planation through much of the west that on the border just south of the Tropic of Capricorn a step-faulted scarp of horizontal Ordovician sandstones 100 feet high is so prominent above the smooth plains as to have merited the name of the Toko Ranges.

The drainage systems of the 'Lake Eyre' cycle are choked with two sets of alluvia, an older, red, and a younger, grey. The former are often extensively eroded, as in the Carpentaria drainage. The latter, constituting vast inland deltas, are responsible for the amazing reticulatory drainage patterns of the Australian interior river systems. That of the Warrego has been described as "larger in area than the great deltas of the Nile, the Congo, the Indus, the Irrawaddy and the Mississippi." The abundant alluvia are due partly to the ready supply of debris from the Cretaceous and early Tertiary beds of the Great Artesian Basin and partly to the exceedingly low gradients of most of the streams. Of similar reticulations in the drainage patterns of strongly-flowing incised streams peripheral to the Barkly Tableland Whitehouse (1940a, p. 50) opines that they have been superimposed from earlier braided courses developed upon a plain. The plain in question may then have been an early phase of the 'Lake Eyre' cycle.

In the Moreton district, where the 'Australian' pediplain forms the crest at above 4000 feet, the 'Lake Eyre' cycle stands at 2600 feet. The line of the divide has been forced to the west by younger cycles acting from the coast, so that wind-gaps now appear at the heads of certain of the westward-flowing rivers (Wearne and Woolnough 1911, pp. 138-9). These events were followed by the usual extensive Kosciusko block movements. Andrews (1910) has emphasized the essential unity of 'post-Australian' erosional and tectonic events in eastern Australia, which should now be brought out by geomorphic mapping in the field.

All about Australia one of the last movements has been a drowning of 150-200 feet, remarkably like that which has affected the African continent.

Conclusion

The paper endeavours to demonstrate in Australia a connected and fairly uniform landscape history, and thereby to provide a geomorphologic skeleton upon which may be hung the multitude of physiographic facts which constitute the scenery of the country.

Clearly the landscapes fall into four sharply divided groups: (i) ancient landscapes ('Gondwana') older than the present configuration of Australia; (ii) a group of landscapes whose evolution began in Cretaceous and ended near the coasts in Miocene times, the extreme expression of which is the laterite-capped 'Australian' pediplain; (iii) more varied landscapes (initiated in the Miocene), the older of which have reached advanced planation, with destruction of much of the great 'Australian' pediplain; and (iv) a series of small local cyclic landscapes and phases following the powerfully differential movements of the Kosciusko orogeny, and later dislocations.

Basining and tilting sometimes caused uplift in one place and depression in another, as with the 'Gondwana' landscape of early Cretaceous time in Western Australia and the Queensland-New South Wales interior respectively.

It is suggested that, by submitting the landscape to investigation by quantitative methods, as by mapping the distribution of the main cyclic landscapes, a very complete story can be made out for the scenic evolution of Australia.

The skeleton being out of the cupboard, we must now confess that, with the exception of the fourth group of landscapes listed above, induced by the Kosciusko movements, the history is the same generally as that already demonstrated for South Africa (King 1949), where occur also: remnants of 'Gondwana' landscapes; an 'African' pediplain, most widespread of all the land-surfaces of the subcontinent, and developed principally between the Cretaceous and Miocene periods; and a third series of more varied, polycyclic landscapes.

Whether this correspondence is to be interpreted as a function of continental drift, or of other synchronous global influence, is a point for later solution.

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4

THE PETROLOGY OF THE CAINOZOIC BASALTIC ROCKS OF TASMANIA

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Introduction

Cainozoic basaltic rocks outcrop over an area of about 1,600 square miles, or about 6 per cent, of the land surface of Tasmania; and from the distribution of present outcrops it would appear that the basaltic magma from which they were derived underlay an area of perhaps 15,000 square miles. As may be seen from Fig. 1, they are most extensively developed in the north-west of the island, particularly in the triangular area extending westwards from Deloraine to Waratah and Preolenna. In this region they occur as a series of extensive lava fields [13, 3] capping parts of the seaward sloping plateau surface that is known as the North-Western Peneplain.[19] The plateau has been deeply dissected by streams flowing into Bass Strait, leaving the basalt as a flat capping, about 100 feet thick, on the ridges and broader plateau areas between the valleys. The surfaces of the basalt plains are diversified by the shallow valleys of streams that are as yet confined to the plateau surface (upland or hanging streams), and by occasional more or less conical hills marking points of eruption (Plate III, fig. 5). In places the plateau surface rises step-fashion across small scarps that trend parallel to the north coast. Further to the west there are extensive basaltic areas south of Smithton, and near Marrawah and Balfour.

Numerous areas of basaltic rock occur in eastern and central Tasmania, at varying elevation. These are commonly confined lava fields,[13, 3] not extending beyond the interfluves of the pre-basaltic valley into which the basalt erupted.

In the north-east such lava fields have infilled the old valleys of Pipers River and Pipers Brook, St. Patrick's River, the Little Forest Rivulet, Bessel's Rivulet, and the Ringarooma River. Small lava fields occur east of St. Leonards and between Perth and Breadalbane, fringed by small residuals. Basalt flows filling old valleys occur on the Central Plateau, in the vicinity of the Great Lake, Lake Sorell, and along the Nive River, and occur as small residuals capping a number of isolated hills along the margin of the Western Tiers. In the Midlands, basalts form broad plains in the old valleys of the South Esk and Macquarie Rivers, the latter field extending from Conara Junction to Tunbridge. Small conical hills, marking points of eruption, can be observed in the vicinity of Campbell Town, Conara Junction, and Fordon (south of Nile).

In the south-east, basaltic areas are found at Bridgewater, at Campania, in the valley of the Coal River, and near Sorell at the head of Pitt Water, and in the vicinity of Rokeby. Basaltic residuals occur at intervals along the valley of the Derwent at New Norfolk, Macquarie Plains, Hamilton, Glenora and at Ouse; and isolated small areas lie south of Hobart, near Kingston, Ranelagh and Hythe.

In addition several unusual differentiated basaltic types outcrop as small volcanic cones or plugs on Shannon Tier.

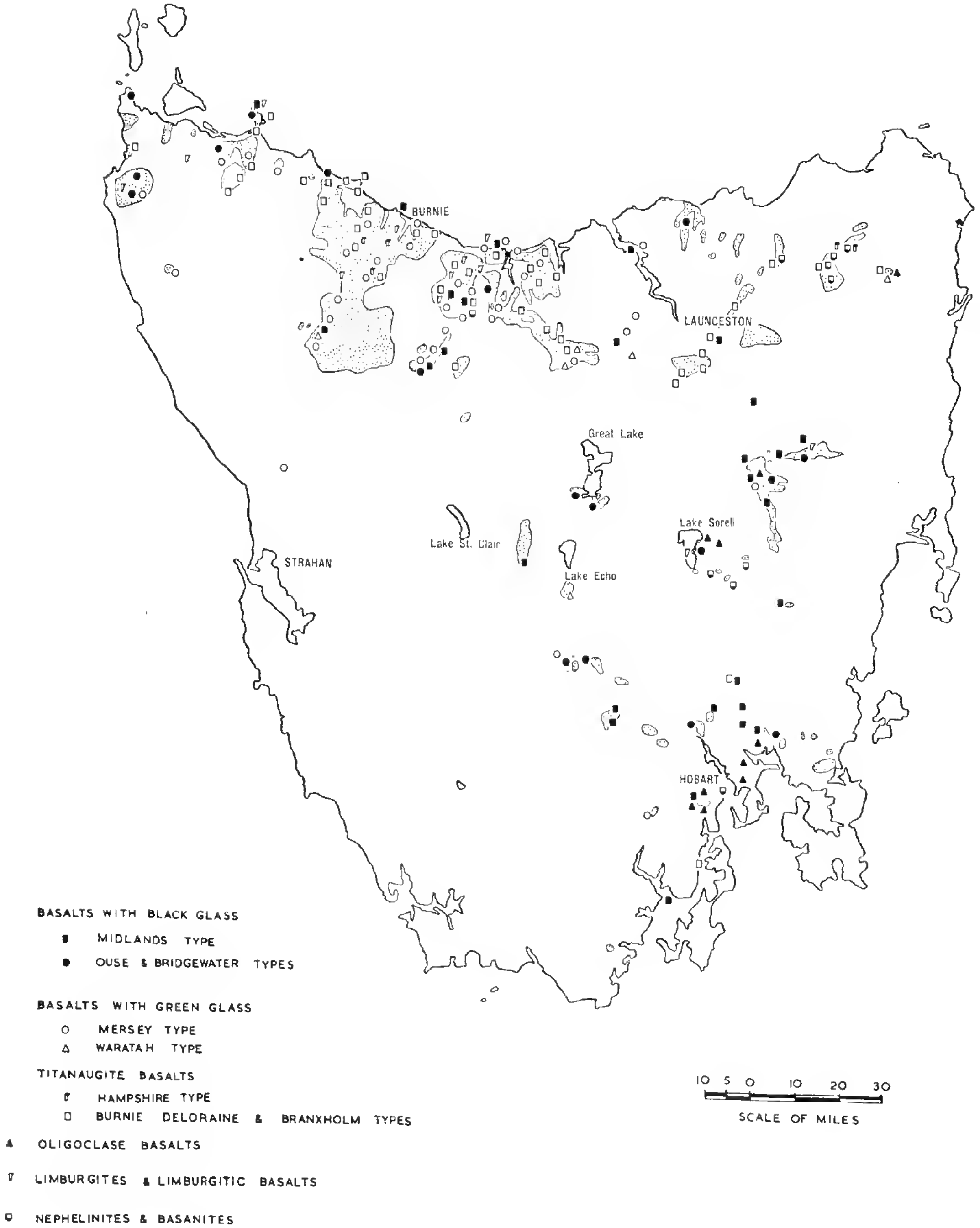

FIG. 1.—Relative distribution of Basalt Types in Tasmania.

Age of the Basalts

The age of the basalts is not everywhere well established. In the neighbourhood of Wynyard they overlie Miocene marine sediments, and in the vicinity of Launceston and Hobart they overlie leaf-bearing sediments of the Launceston Basin and the Derwent Basin, so that in these areas they are regarded as Pliocene or younger.[12] A similar age has been assigned to most of the occurrences in eastern Tasmania,[19, 3] chiefly on physiographic grounds.

A Miocene or pre-Miocene age has been established for certain basalts at Marrawah, in north-western Tasmania,[19] and there is a tendency to correlate the basalts capping the dissected plateaux of the North-Western Peneplain (the Waratah and Middlesex Plains basalts), and the residuals of high level basalts along the margin of the Western Tiers, and at Branxholm and Weldborough, in north-eastern Tasmania, with these pre-Miocene basalts of Marrawah.

The Pliocene, or younger, basalts have been correlated tentatively with the basalts of the Newer Volcanic Series of Victoria, and the pre-Miocene basalts with the basalts of the Older Volcanic Series of Victoria.

Petrology

Previous Work

The earliest petrological study of Tasmanian basaltic rocks was made by Ulrich,[12] who recognized the presence of olivine basalts among them, and also recorded a nephelinite (possibly one of the nepheline-bearing rocks of Shannon Tier). This early examination was amplified by the studies of Twelvetrees,[24] summarized in his statement of 1908, which records the prevailing types as 'basalts and olivine-basalts,' with occasional developments of limburgite and more alkaline types, as at Table Cape, Circular Head, Shannon Tier and Sandy Bay. No detailed account of these rocks was published, however. Aurousseau[1] analysed and described in detail the nepheline basanite of Sandy Bay; and Paul,[20] and later Erdmannsdorffer and Nieland[9] and Tilley,[22] gave detailed descriptions and analyses of the melilite-bearing nepheline basalts of Shannon Tier. Brief petrological accounts of local basalt occurrences are recorded in several bulletins of the Geological Survey of Tasmania, notably Bulletin No. 41 (Smithton District), which includes two chemical analyses; and Edwards[6] has described the differentiated crinanite laccolith of Circular Head (Stanley), with five chemical analyses.

This Paper

The object of this study was two-fold—(1) to provide a more detailed petrological account of the Tasmanian basaltic rocks, and (2) to discover whether any petrographic distinction can be drawn between supposedly 'Older' and 'Newer' basalts, such as obtains in Victoria.[4, 5] It is based upon the examination of more than 300 specimens collected as 'grab samples' during a number of journeys designed to traverse most of the major and minor basaltic areas in Tasmania. It can be expected that this method of collecting has failed to include some of the rarer and more strongly differentiated rock types, which would normally be of small volume; but it has provided a reliable sample of the prevailing rock types, and so yields a picture of the petrological character of this basaltic province, from which the likely nature of strongly differentiated rock types that may occur, but are not represented in the collection, can be deduced.

Rock Analyses

Eleven new chemical analyses are presented. These were made by Mr. W. St. C. Manson and his associates, of the Mines Department Laboratory, Launceston, by permission of the Director of Mines for Tasmania, in connection with a study of the bauxites of Tasmania, which required as an integral part a knowledge of the petrological characters of the basaltic rocks.

The Rock Types

The rocks of the collection consist predominantly of a variety of olivine-basalts, with associated limburgites, limburgitic-basalts, olivine-nephelinites and nepheline-basanites, all clearly the differentiation products of an olivine-basalt magma type. The melilite-bearing nepheline basalts and fasinite of Shannon Tier so closely resemble the nephelinites and basanites that they must be included as more extreme differentiates of this magma. Other differentiated types are the oligoclase-basalts of the south-east, the highly felspathic olivine-basalt of the Smithton district in north-western Tasmania, and the nepheline-bearing facies in the Circular Head laccolith. No acid or intermediate extrusives have been found, but if they occur they can be expected to be of a phonolitic or trachytic character. It is possible that the syenite-porphyry stock of Port Cygnet and its related dykes(8) are differentiates of this olivine-basalt magma, but the only evidence for this is a possible similarity in age between these rocks and some of the basalts, and the trachyte-like character of some of the dyke rocks.

Classification

The more differentiated rock types in the collection are easily distinguished microscopically and chemically, and are readily classified, but the basalts are more difficult to classify. Some of them are sufficiently distinctive in thin section to be grouped into types or varieties that recur in different parts of Tasmania. Descriptions of the characteristic features of these types are set out in the following sections, amplified by photomicrographs. Chemical analyses have been made of representative specimens, and the analyses show variations in chemical composition in keeping with the petrographical variations; but there are too few chemical analyses of any one type, or of related types, to establish the full significance of textural variations.

The bases of classification are three, and are given in the order of their apparent significance:

(i) the *type of pyroxene* predominating, whether augite or titanaugite;

(ii) the *texture of the groundmass,* whether ophitic, intergranular, or intersertal, and the relative proportions of felspar, pyroxene and glass, with especial emphasis on the *nature of the glass*, whether green or black;

(iii) the nature and relative proportion of the phenocrysts, olivine, plagioclase and pyroxene.

On these bases, nine types of basalt have been established, as indicated in Table 1. For convenience of reference, each type has been given a distinguishing name, such as *Midlands Type,* or *Mersey Type*. The names derive from a district or locality in which the type is typically developed, and are intended for local use only. Some of the types are of wide occurrence, others are more restricted, as may be seen from Fig. 1, in which the location and classification of the specimens in the collection are shown.

TABLE 1

Petrographic Classification of the Widespread Types of Basalt in Tasmania.

Groundmass		Phenocrysts			SiO_2 Content %
Type of Pyroxene	Texture	Olivine	Olivine + Pyroxene	Olivine + Plagioclase	
Absent or vestigal (colourless)	Intersertal, with abundant *black* glass	OUSE TYPE	—	—	50-51
Colourless augite	Intersertal to intergranular, with abundant *black* glass	BRIDGE-WATER TYPE	—	—	50-51
Colourless augite	Ophitic to intergranular, with or without a little *brown* or *black* glass	MIDLANDS TYPE	—	—	50-51
Colourless augite	Intersertal to intergranular, mostly with some *green* glass	MERSEY TYPE	—	WARATAH TYPE	48
Titanaugite	Ophitic, medium to coarse-grained	DELOR-AINE TYPE	HAMP-SHIRE TYPE	—	44-45
Titanaugite	Ophitic patches, flow structure	BURNIE TYPE	—	—	44-45
Titanaugite	Intergranular	BRANX-HOLM TYPE	—	—	44-45

As might be expected, a number of specimens are intermediate between two or more types, and from such transitional relations it appears that there are three main groups of olivine-basalts in Tasmania:

(1) *basalts with black glass*: Midlands Type, Bridgewater Type, Ouse Type;
(2) *basalts with green glass*: Mersey Type, Waratah Type;
(3) *basalts with titanaugite*: Hampshire Type, Deloraine Type, Burnie Type, Branxholm Type.

The close relationships of the members of these three groups is borne out by their similarities in chemical composition, as may be seen from the analyses of specimens selected as representative, in Tables 2, 3 and 4.

Basalts with Black Glass

Olivine-basalts containing more or less black glass comprise 20 to 25 per cent of the collection. Three related basalt types containing such glass can be distinguished. The three types are of similar chemical composition (Table 2) but are texturally distinct, though a gradation from one type to another can be traced, corresponding to a progressive crystallization of the glassy mesostasis.

Ouse Type

These rocks consist of corroded idiomorphic phenocrysts and microphenocrysts of fresh or serpentinized olivine, grading down to granules, and small laths of plagioclase, set in an abundant mesostasis of black glass (Pl. I, fig. 1). The plagioclase is labradorite, of a composition about An_{60}, and some crystals have hollow cores that have become filled with the black glass. The felspar laths generally show a random arrangement, but an exception is provided by a specimen from Marrawah, in which there is well marked flow alignment.

The glass, when resolved under high magnification, is found to consist of myriads of minute granules of iron ore in a brownish glass, which is traversed by feathery 'ghosts' or skeletal crystals of pyroxene and felspar. Occasional patches of green glass (brown in some weathered specimens) occur in the black glass, and calcite may accompany such green glass. In some specimens, particularly those from Ouse, the skeletal crystals of pyroxene and felspar in the black glass occur as curving sheaves of microlites that form a striking dendritic pattern (Pl. I, fig. 1). These sheaves have been termed *keraunoids*[25] and *sphaerokrystalle*.[10]

An analysis of a representative specimen from Ouse is given in Table 2, No. 1. The chief features of the analysis are the high SiO_2 content, as compared with the titanaugite-basalts (Table 4), the lower magnesia content, MgO and CaO being in about equal proportions, and the low potash content. Titania and phosphorus also tend to be low.

TABLE 2

Analyses of Basalts with Black Glass in the Base

	1.	2.	3.	A.	B.
SiO_2	51·48	51·48	50·04	50·44	49·86
Al_2O_3	14·32	14·18	14·47	14·47	14·35
Fe_2O_3	2·17	1·56	4·26	6·32	4·21
FeO	8·98	9·61	7·69	5·01	7·02
MgO	8·02	8·18	7·89	7·93	8·25
CaO	8·33	8·95	9·35	8·75	8·45
Na_2O	2·48	2·61	2·47	2·59	2·80
K_2O	0·61	0·82	0·26	1·11	1·23
H_2O+	0·58	1·00	1·43	0·60	—
H_2O-	1·54	0·24	0·52	0·60	—
CO_2	0·05	tr.	tr.	nil	0·04
TiO_2	1·45	1·60	1·55	1·80	1·62
P_2O_5	0·21	0·29	0·23	0·31	0·38
MnO	0·14	0·15	0·17	0·19	0·18
Cl	nil	tr.	tr.	nil	—
SO_3	nil	tr.	tr.	nil	—
	100·16	100·67	100·33	100·12	—

1. Ouse Type, glassy olivine-basalt (Pl. I, fig. 1), from near Ouse township. *Analyst*: W. St. C. Manson.
2. Bridgewater Type, olivine-basalt with intersertal black glass, from 400 yards upstream above bridge, Bridgewater township (Pl. I, fig. 2). *Analyst*: W. St. C. Manson.
3. Midlands Type, iddingsitized olivine-basalt, with a tendency to black intersertal glass, from Viney's Sugarloaf, at Fordon No. 22 lateritic bauxite deposit, south of Nile (Pl. I, fig. 3). *Analyst*: W. St. C. Manson.

A. Iddingsitized olivine-labradorite-basalt (Footscray Type), from the Newer Volcanic Series, municipal quarry, Warrnambool, Victoria (Edwards, Ref. 5, p. 209).

B. Average of 16 olivine-labradorite-basalts, from Newer Volcanic Series of Victoria (Edwards, Ref. 5, pp. 209, 284).

Bridgewater Type

With a slight increase in crystallinity, the potential augite in the black glass of the Ouse basalts appears as uniformly distributed granules, and the black glass is restricted in amount, so that the appearance of the rock in thin section is quite changed (Pl. I, figs. 2, 3), despite the fact that there is little or no change in chemical composition, as may be seen by comparing Analyses 1 and 2 of Table 2. The resultant rock consists of phenocrysts of olivine, which are commonly slightly resorbed, in an intersertal groundmass of plagioclase laths, augite granules and black glass. In some specimens a proportion of the felspar laths are sufficiently developed to appear as microphenocrysts. The pyroxene tends to be brownish, and has a positive optic axial angle of more than 45°, indicating that it is augite.

This variety of basalt is widely distributed throughout Tasmania (Fig. 1). The occurrence at Bridgewater was selected as typical and conveniently available. An analysis of a specimen from this locality (Table 2, No. 2) shows that it is a silica-rich basalt, practically identical in composition with the analysed Ouse basalt.

Midlands Type

This basalt type, named from its widespread occurrence in the Midlands region, represents the product of more or less complete crystallization of the black glass. The rocks are commonly grey, and finely vesicular, and consist of phenocrysts of olivine in an intergranular groundmass of labradorite laths, brownish augite of varying coarseness of grain size, but generally granular and ophitic or sub-ophitic towards the felspar laths, and lath-shaped crystals of ilmenite. In some specimens the granular augite crystals have become 'welded' into larger ophitic plates, but this is not common. A little dark glass is commonly preserved in the interstices, but is absent in some specimens. The olivine phenocrysts commonly have a narrow rim of iddingsite, but this is not always developed. The appearance of a typical specimen in thin section is shown in Pl. I, fig. 4.

The basalt outcropping at Viney's Sugarloaf, a distinctive small point of eruption close to Fordon, was selected for analysis. This Sugarloaf is just west of the road from Nile to Conara, about midway between Nile and the bridge over the South Esk. Its close resemblance in composition to the Ouse and Bridgewater basalts is apparent (Table 2, No. 3). The higher Fe_2O_3 content of the Viney's Sugarloaf rock reflects the partial conversion of the olivine phenocrysts to iddingsite. The low K_2O is possibly abnormal.

Comparison with Victorian Basalts

As may be seen from Table 2, this group of basalts, the Ouse, Bridgewater and Midlands Types, closely resembles in chemical composition the widespread Footscray type of the Newer Volcanic Series of Victoria. In the case of the Midlands basalts, the resemblance extends to the microtexture and mineral composition, the alteration of the olivine to iddingsite, the presence of black glass, and the grey colour and vesicular character of hand specimens. The Ouse basalts cannot be matched in Victoria, but occasional flows in Victoria resemble the Bridgewater type.

Basalts with Green Glass

Two closely related types of olivine-basalt, with green intersertal glass, and differing chiefly in the nature and proportion of their phenocrysts, are strongly developed in northern Tasmania (Fig. 1).

Mersey Type

This type of basalt is widespread, particularly in the region between Deloraine, Waratah and Preolenna. It consists of idiomorphic to slightly corroded phenocrysts of olivine, set in a groundmass of stumpy plagioclase laths, lath-like iron ores (ilmenite), granular, colourless to pale-brown augite, and pale-green glass, which resembles serpentine when devitrified. The texture is intergranular to intersertal, depending on the proportion of glass present, and the grain size of the groundmass varies somewhat. In the coarser-grained varieties (Pl. I, fig. 5) the olivine phenocrysts are about 0·5 to 1 mm. across, the smaller size being the more common. They have 2V about 90°, and are optically positive (in some instances negative), so that their composition is about Fo_{85}. They commonly show partial alteration to serpentine, the serpentine developing along fractures and around the margins of the crystals. In some sections there are occasional phenocrysts of labradorite, and somewhat inchoate phenocrysts of augite, marking a transition to the Waratah type of basalt, described below.

The groundmass plagioclase is a labradorite, with a maximum extinction angle in the symmetrical zone of about 33°, indicating a composition of about Ab_{35}. It occurs as laths 0·1 to 0·15 mm. long and 0·01 mm. thick. In some specimens the laths show a sub-parallel arrangement, as a result of flow. More often, however, they show random orientation. The iron ore laths, chiefly ilmenite, or ilmenite with intergrown lamellae of magnetite, are about 0·1 mm. long, and the pyroxene granules are about 0·05 mm. across, some of them prismatic. In some specimens, particularly those with flow texture, the pyroxene granules tend to form fringes around the olivine phenocrysts; and in some of the coarser-grained rocks they have coalesced to form inchoate phenocrysts, or coarser grains that tend to be sub-ophitic towards the felspar.

TABLE 3

Analyses of Basalts with Green Glass in the Base

	1.	2.	A.
SiO_2	48·28	48·40	47·54
Al_2O_3	14·01	15·59	14·16
Fe_2O_3	3·13	5·12	3·02
FeO	8·45	6·29	8·89
MgO	9·18	6·52	8·86
CaO	9·35	7·95	9·18
Na_2O	2·96	2·69	3·25
K_2O	0·89	1·09	1·88
H_2O+	1·29	2·40	0·55
H_2O-	0·40	1·74	1·47
CO_2	0·06	tr.	nil
TiO_2	2·10	1·88	0·90
P_2O_5	0·39	0·36	0·44
MnO	0·15	0·14	0·30
Cl	tr.	tr.	0·06
SO_3	tr.	tr.	nil
BaO	—	—	0·03
	100·66	100·17	100·63

1. Mersey Type, olivine-basalt, from outcrop on beach, east side of Mersey Bluff, east of Recreation Reserve. (Pl. I, fig. 5.) *Analyst*: W. St. C. Manson.
2. Waratah Type, olivine-labradorite-basalt, north end of Waratah township. (Pl. I, fig. 6.) *Analyst*: W. St. C. Manson.

A. Trentham Type, olivine-basalt, allotment 79, parish of Trentham, Victoria (Newer Volcanic Series). (Edwards, Ref. 5, p. 284.)

Green glass is present in varying amount in the interstices. In a few specimens the iron ores have not crystallized completely, and the green glass is studded with globules and trichytes of iron ore that give it a dark appearance under low magnification. In some of the finer-grained specimens of this type of basalt, the pyroxene appears rather more abundant in the groundmass than is the case with the coarser-grained basalts, and the iron ores occur as squarish crystals, indicating that they are predominantly magnetite.

The basalt outcropping at sea-level on the east side of Mersey Bluff, near Devonport, which is a moderately coarse-grained variety (Pl. I, fig. 5), was selected as typical, and an analysis was made of this rock (Table 3, No. 1). Comparison of this analysis with those of Table 2 indicates that the Mersey basalts, though generally similar in composition to the group of basalts with black glass, contain somewhat less silica, and slightly more magnesia, soda and phosphorus.

Waratah Type

Closely related to the Mersey Type, and occurring in the same regions, but to a more limited extent, is the Waratah Type of basalt. This differs from the Mersey Type in the presence in it of phenocrysts of labradorite, as laths up to 1·0 x 0·2 mm., in about the same abundance as olivine, and occasional phenocrysts of pale-brown augite, from 0·25 to 1 mm. across. The augite is optically positive, with 2V about 50°, and tends to occur in small clots, associated with olivine phenocrysts (Pl. I, fig. 6). Some augite phenocrysts are inchoate, and appear to result from the 'welding' together of small granular crystals of augite, such as occur in the groundmass.

The basalt outcropping at the northern end of Waratah township was selected as typical, and a chemical analysis of this rock is given in Table 3, No. 2. It closely resembles the Mersey Type in composition, but has a somewhat higher Al_2O_3 and lower MgO content, corresponding to the greater abundance of felspar and the lesser amounts of olivine and augite in this rock.

Comparison with Victorian Basalts

The Mersey basalt has an almost identical counterpart in the Trentham basalt of the Newer Volcanic Series of Victoria, though, as may be seen from the analyses of Table 3, the Victorian rocks tend to be richer in potash and poorer in titania than their Tasmanian equivalents. The Mersey basalt also bears a considerable resemblance to the Flinders basalt of the Older Volcanic Series of Victoria.

The Waratah basalt bears a general resemblance to the Gisborne basalt of the Newer Volcanic Series in Victoria, the Gisborne basalt being related to the Trentham basalt much as the Waratah basalt is to the Mersey Type. The Gisborne basalt tends, however, to contain a little hypersthene, a feature not noted in the Waratah basalt.

Comparison of the analyses of Table 3 with those of Tables 2 and 4 indicates that these basalts with green glass have a chemical composition intermediate between those of the basalts with black glass, and the titanaugite basalts.

Basalts with Titanaugite

Basalts containing titanaugite are strongly developed in northern Tasmania—at Branxholm, Scottsdale, Derby and Weldborough in the north-east; near Perth, Longford, Deloraine, Harford and Latrobe in the centre; and in the Burnie, Smithton and Wynyard districts in the north-west—but they do not occur to any

extent in the Midlands or in the south-east. They are commonly associated with Mersey and Waratah basalts.

Five types of titanaugite basalt may be recognized on the basis of recurrent textural differences, but the chemical analyses available of these types (Table 4) show that with the exception of the Smithton type they are practically identical in composition. Presumably the textural differences are related to degree of crystallization prior to extrusion, to the rate of chilling after extrusion, and to variation in content of water and other variables, as indicated by the presence of analcite in some types.

TABLE 4

Analyses of Basalts with Titanaugite

	1.	2.	3.	4.	A.	B.
SiO_2	44·12	45·44	43·76	43·35	44·91	45·86
Al_2O_3	13·94	14·52	13·55	13·50	13·77	13·19
Fe_2O_3	2·60	1·27	3·90	2·62	5·28	2·82
FeO	8·98	10·68	7·20	10·94	5·81	8·61
MgO	11·43	11·12	10·24	11·84	12·19	10·58
CaO	9·40	8·23	8·28	9·85	8·56	9·09
Na_2O	2·83	2·95	1·70	3·02	1·73	2·44
K_2O	1·99	1·41	0·47	1·18	0·94	1·00
H_2O+	0·10	0·32	6·68	0·15	3·40	1·33
H_2O-	1·94	2·62	2·06	1·74	1·34	1·66
CO_2	tr.	tr.	tr.	nil	tr.	0·60
TiO_2	2·30	1·83	1·63	2·25	7·73	2·20
P_2O_5	0·55	0·40	0·35	0·71	0·32	0·51
MnO	0·14	0·14	0·12	0·11	0·33	0·24
Cl	nil	nil	tr.	—	nil	tr.
SO_3	nil	nil	0·15	—	nil	nil
	100·32	100·56	100·09	100·34	100·39*	100·16**

*NiO 0.03
CoO tr.
Cr_2O_3 0.05

**NiO 0.03

1. Hampshire Type, olivine-titanaugite-basalt (Pl. II, fig. 1), with macro-phenocrysts of titanaugite, 3 to 5 mm. diameter, from prominent point of eruption east of Emu Bay railway line, a short distance north of Hampshire Railway Station. *Analyst*: W. St. C. Manson.
2. Burnie Type, olivine-titanaugite-basalt (Pl. II, fig. 2), from road cutting above Burnie Park (south of), Burnie. *Analyst*: W. St. C. Manson.
3. Deloraine Type, olivine-titanaugite-basalt (Pl. II, fig. 3), from core of a somewhat weathered boulder enclosed in deeply weathered material, road cutting at sharp bend midway between Deloraine and Elizabeth Town. *Analyst*: W. St. C. Manson.
4. Olivine-titanaugite-basalt from 70 ft. above the chilled base (olivine enriched layer) in the Circular Head laccolith. (Edwards 1941, p. 407.)

A. Mirboo Type, basalt, Older Volcanic Series of Victoria, from Berry's Creek Bore No. 20, depth 90 ft., allot. 34, parish of Mardan, Victoria. (Edwards, Ref. 4, p. 90.)

B. Camperdown Type, olivine-labradorite-basalt, Newer Volcanic Series of Victoria, from Harvey's Well, top flow, allot. 26, parish of Colongulac, Victoria. (Edwards, Ref. 5, p. 288.)

Hampshire Type (Titanaugite Porphyries)

Distinctive coarsely porphyritic titanaugite-olivine-basalts occur as a point of eruption and flow from it on the east side of the railway line just north of Hampshire railway station (Pl. III, fig. 5); as a flow at a point about six miles from Somerset on the road from Somerset to Yolla; as a flow about six and a half

miles from Burnie on the road to Ridgely; and at Mara, in north-eastern Tasmania. Related rocks, in which the titanaugite is ophitic rather than phenocrystic, occur on the road from Deloraine to Devonport at 33 miles from Launceston, and at Main Creek, near Derby.

In the Hampshire, Mara, Yolla and Burnie rocks the titanaugite is present as phenocrysts 5 mm. or more in diameter. These phenocrysts are composite rosettes, in which the individual crystals show idiomorphic outlines, with re-entrant angles towards the groundmass, and allotriomorphic faces towards one another (Pl. II, fig. 1). Small inclusions of olivine and plagioclase have been caught up as inclusions during the growth of the clusters. The titanaugite is strongly zoned, as many as 30 narrow zones being present in a single crystal. It is optically positive, with 2V greater than 45°, and is strongly pleochroic with X = deep violet, Y = pale violet, Z = light yellow.

Associated with the titanaugite phenocrysts are smaller idiomorphic or rounded phenocrysts of olivine, and micro-phenocrysts of magnetite, some of which have skeletal forms. The phenocrysts are set in a variable proportion of fine-grained groundmass, with an intergranular to intersertal texture, consisting of short plagioclase laths, granules of titanaugite, skeletal iron ore, apatite needles and colourless to greenish felspathic glass. The plagioclase is labradorite, of composition about Ab_{40}. The Burnie and Yolla specimens have fewer titanaugite phenocrysts than the other two, but have more and coarser crystals of titanaugite in their groundmass.

The rock from between Deloraine and Devonport contains very little olivine, and in this rock the abundant zoned, purple titanaugite occurs in clusters of crystals which are ophitically intergrown with plagioclase laths about 0·5 mm. long. The iron ore is coarse-grained, and scattered through an abundant glassy base, which is studded with myriads of fine skeletal rods of iron ore, oriented in parallel or rectangular growths, or in triangular lattices. Associated with the groundmass are occasional small flakes of red biotite, pleochroic to straw yellow.

The Derby rock is ophitic, but in it both the titanaugite and the labradorite occur as crystals 2 to 3 mm. across, ophitically intergrown with one another. Olivine occurs only as occasional corroded phenocrysts, much smaller than the plagioclase and titanaugite grains, and there is only a small proportion of fine-grained groundmass. This consists of small plagioclase laths, skeletal rods of iron ore, apatite needles, titanaugite, and a greenish glass felted with microlites of felspar. The glass is sodic, since titanaugite associated with it is fringed with green aegirine-augite.

These rocks bear some resemblance to specimens of analcite-olivine-titanaugite-dolerite from the Table Cape and Circular Head laccoliths.

A chemical analysis of the Hampshire rock is shown in Table 4, No. 1. It is distinctly undersaturated with respect to silica, and has a rather low alumina content. This, together with the high MgO, CaO and TiO_2, reflects its richness in titanaugite and olivine. The potash content of this rock is unusually high for Tasmanian basalts so far analysed. Presumably the felspathic glass is potassic.

Burnie Type

Basalts of this type are prominently developed in the vicinity of Burnie, Somerset and Seabrook, and in the vicinity of Harford, Sassafras and Latrobe. They consist of rounded phenocrysts of olivine, set in a relatively fine-grained groundmass, consisting of small olivine granules, narrow laths of plagioclase, abundant purple titanaugite, coarse iron ores, coarse needles of apatite, a little

felspathic glass and, in some instances, some analcite. The plagioclase is labradorite, about Ab_{40}, and the titanaugite is strongly pleochroic from deep violet to pale straw with a positive optic axial angle greater than 45°. The distinctive features of this group of rocks is the characteristic occurrence of the titanaugite as isolated, more or less lens-shaped patches, which are in intimate ophitic intergrowth with sheaves of narrow sub-parallel plagioclase laths (Pl. II, fig. 2). The titanaugite areas show up strikingly when viewed with crossed nicols.

Where analcite is present in any abundance it occurs in interstitial patches, and has replaced the felspar in part. Such rocks approximate to crinanite-basalts.

The excellent exposure of fresh rock in the cutting on the road that rises above Burnie Park on its south-east side, at Burnie West, was selected as the type locality, and an analysis was made of this rock. The analysis (Table 4, No. 2) closely resembles that of the porphyritic Hampshire basalt. The slightly higher SiO_2 and Al_2O_3, and lower CaO suggest that it contains slightly more felspar and less titanaugite than the Hampshire rock, but the differences are not very significant.

Deloraine Type

This variety of basalt may be regarded as a coarse-grained variation of the Burnie Type (Pl. II, fig. 3). The olivine phenocrysts tend to be larger and more clustered than in the Burnie Type, and the ophitic titanaugite is gathered into larger crystals, with fewer intergrown felspar laths. Moreover, the felspar laths in the ophitic intergrowths lack the parallel orientation of their counterparts in the Burnie basalts, as may be seen from a comparison of the photomicrographs of Pl. II, fig. 2, and Pl. II, fig. 3, which are of the same magnification. As a result, the colourless patches of groundmass, consisting chiefly of plagioclase laths, appear larger and more prominent in the Deloraine basalts.

An analysis of a slightly weathered specimen of the Deloraine Type—selected for analysis in connection with a study of the weathering of Tasmanian basalts in relation to the origin of bauxites, rather than for the purpose in hand—is shown in Table 4, No. 3. When allowance is made for its weathered condition, its close resemblance to the analyses of the Burnie and Hampshire Types is apparent. An analysis of a fresher example of a basalt of this type is provided by that of the olivine-enriched layer in the Circular Head laccolith (Table 4, No. 4). This analysis is somewhat richer in iron oxides, but closely resembles the others of this group, and in particular that of the Hampshire Type.

From these similarities it is apparent that there is little if any significant difference in the mineral composition of these three rock types. The difference is only in texture, and this is a reflection of the conditions attending the crystallization of the titanaugite. In the Burnie rock the titanaugite had scarcely begun to crystallize when extrusion occurred. The titanaugite crystallized ophitically about the felspar laths after extrusion had occurred, so that the flow alignment of the felspar laths is incorporated in the ophitic patches. Even so, cooling was sufficiently slow to permit considerable diffusion, or else the lens-like crystals of titanaugite could not have formed. In the Deloraine rocks the titanaugite apparently crystallized prior to extrusion, so that the felspar laths included in the ophitic areas show no flow alignment, and are fewer, though not necessarily larger. The slower onset of crystallization permitted freer diffusion in the melt, with correspondingly fewer centres of crystallization and larger growth of individual titanaugite crystals, making for larger interstitial areas of predominant felspar.

In the Hampshire rocks the crystallization of the titanaugite either commenced at a higher temperature or, more probably, the period between initiation of its crystallization and extrusion of the magma was longer. As a result of prolonged free diffusion in the melt the clusters of early-formed titanaugite crystals were able to grow large, pushing aside, rather than incorporating, the olivine and felspar crystals in the melt, except where these were trapped between adjacent titanaugite crystals. After the individual crystals of the clusters came into contact, their external surfaces continued to grow freely, forming glomeratic macrophenocrysts bounded by crystal faces, with more or less obtuse re-entrant angles between individual crystals of the cluster. The high CaO content of the Hampshire rock suggests that there was some gravitative concentration of the augite during the period prior to extrusion, and the prominent zoning points to their being carried about by convection currents during their period of growth.

These three basalt types can be regarded, therefore, as closely related variants of the same magma, deriving their textural differences from different lengths of cooling prior to extrusion. As might be expected, there are titanaugite basalts transitional between these types. The Burnie Type might be expected to approach most closely in composition to the source magma.

Branxholm Type

Where conditions, presumably rate of cooling, inhibited diffusion, myriads of crystallization centres developed, as cooling forced on crystallization, and basalts with intergranular textures resulted, in which the titanaugite is restricted to minute prisms and granules, with only an incipient tendency to form ophitic intergrowths with the felspar laths. In such rocks the groundmass appears darker from the even distribution of the pyroxene through it. Olivine-titanaugite-basalts of this texture, and with varying coarseness of grain size, are common in northern Tasmania, particularly in the vicinity of Harford. In some specimens the titanaugite occurs in part as microphenocrysts. With decrease in titanium content, they grade insensibly into the basalts of the Mersey Type.

In some of these intergranular titanaugite basalts the plagioclase laths occur partly as microphenocrysts, when the rock becomes a titanium-rich equivalent of the Waratah Type. There is also a tendency in these rocks for the small titanaugite prisms to form clusters and rosettes (Pl. II, fig. 4). Basalts with this habit are developed at Branxholm and Scottsdale in the north-east, at Longford, and near Wesley Vale.

An unusually coarse-grained variant (Pl. II, fig. 5) occurs about seven miles west of Wynyard, on the road to Stanley. In this rock the individual felspar laths are 2 to 3 mm. long, with some tendency to occur in sheaves. The felspar is somewhat analcitized, and there are interstitial areas of colourless glass and analcite, together with a little green chloritic material, and skeletal crystals of iron ore.

Smithton Type

An olivine-basalt of unusual composition occurs as the lowest of three flows in the Smithton district.[18] It consists of phenocrysts of olivine in a relatively coarse-grained groundmass of ophitic titanaugite plates and laths of plagioclase, coarse iron ores, and a little felspathic glass. In thin section the rock appears as a somewhat coarse and felspathic variant of the Deloraine Type, but two chemical analyses (Table 5, Nos. 1 and 2) reveal that the rock has an extremely high alumina content, with a correspondingly high content of lime and alkalis, and a

remarkably low magnesia content. It is clearly a differentiated variety, but one not matched by known basalts elsewhere in Tasmania. The nearest approach to it so far recorded is the rock at the summit of the Circular Head laccolith, but this rock contains more magnesia and less alumina. It appears to represent a magma from which olivine has largely crystallized and sunk, without sufficient accumulation of soda to transform the residue into an oligoclase-basalt or mugearite.

The basalts overlying this felspathic basalt are of the normal types found in north-western Tasmania, including the Mersey Type.

TABLE 5

Analyses of Differentiated Titanaugite Basalts

	1.	2.	3.
SiO_2	44·48	43·68	46·15
Al_2O_3	20·60	21·18	18·95
Fe_2O_3	5·98	1·42	3·68
FeO	7·38	11·45	6·41
MgO	3·73	3·90	5·20
CaO	8·10	8·85	9·15
Na_2O	2·67	2·51	3·79
K_2O	2·01	1·71	2·43
H_2O+	} 1·56	} 1·70	0·20
H_2O-			1·49
CO_2	nil	nil	nil
TiO_2	1·80	1·80	1·65
P_2O_5	0·51	0·44	0·50
MnO	0·91	2·04	0·10
Cl	—	—	—
SO_3	—	—	—
	99·76	100·69	99·70

1. Smithton Type, olivine-basalt, Myrtle Hill, east of Irishtown, Smithton District, probably from the base of the third flow. (Nye *et al.*, Ref. 18, p. 76.)
2. Smithton Type, olivine-basalt, Lileah, Smithton District, probably from the top of the third flow. (*Ibid.*, p. 76.)
3. Differentiated basalt from the summit of the Circular Head laccolith, Stanley. (Edwards 1941, p. 407.)

DIFFERENTIATED BASALTIC ROCKS

Oligoclase-basalts

Fine-grained oligoclase-basalts, of rather unusual chemical composition, occur at a number of localities in south-eastern Tasmania, namely, at Sorell, Cambridge, Rokeby, between Rokeby and Bellerive, at Kingston, between Kingston and Margate, and between Kingston and Longley. These may for convenience be called the Rokeby Type. They consist of idiomorphic phenocrysts of olivine completely altered to iddingsite, with occasional larger phenocrysts in which the iddingsite forms a rim round more or less completely altered olivine, set in a fine-grained groundmass of plagioclase laths and microlites, prisms of brownish pyroxene, abundant small and uniformly distributed granules or octahedra of iron ore, small granules of iddingsite, and some colourless glass (Pl. II, fig. 6). The plagioclase shows almost straight extinction when present as microliths, and a maximum extinction angle of 15° when present as laths, so that it probably has a composition on the borderline between oligoclase and andesine, of about Ab_{70}. A specimen from Rokeby contains a small clot of relatively coarse crystals of labradorite and pyroxene, while one from Kingston contains an inclusion of a fine-grained basaltic rock with corroded but fresh crystals of olivine.

TABLE 6

Analyses of Differentiated Basaltic Rocks

	1.	A.	2.	3.	4.	5.	6.	7.	8.
SiO_2	46·64	45·10	42·44	42·44	39·12	36·17	36.03	37·60	38·35
Al_2O_3	13·22	12·86	12·48	10·24	10·29	11·88	15·19	15·27	10·92
Fe_2O_3	9.81	5·66	9·93	4·38	6·03	11·37	5·94	5·58	8·29
FeO	4·16	7·10	2·84	8·79	8·44	4·17	9.55	6·72	
MgO	7·01	8·56	4·71	14·25	14·03	14·22	8·60	4·78	6·39
CaO	7·33	9·10	8·26	7·75	10·40	11·54	15·52	14·06	22.48
Na_2O	4·11	3·99	5·51	4·18	3·33	5·38	4.23	3·76	7·62
K_2O	1.35	1·02	3·16	1·83	1·23	2·07	1·85	0·87	2·55
H_2O+	0·52	1·53	1·64	0·18	0·88	—	0·58	5·61	—
H_2O-	2·14	1·10	1·73	1·32	2.46	—		1·15	—
CO_2	tr.	tr.	nil	0·36	tr.	—	—	nil	—
TiO_2	2·50	3·50	2·10	2·50	2·73	2.15	1·13	3·78	—
P_2O_5	1·00	1·00	1·65	1·61	1.25	0·84	1·38	0·98	1·33
MnO	0.19	0·08	0·16	0·18	0·18	tr.	0·17	0·28	—
Cl	tr.	tr.	0·16	nil	nil	—	—	0·28	—
SO_3	nil	nil	—	tr.	tr.	—	—	—	—
ZnO	—	—	nil	—	—	—	0.21	—	—
	99·98	100·60	100·06 BaO, 0·05	100·01	100·37	99·79	100·38	100·47	97·93

1. Rokeby Type, basic iddingsite-oligoclase-basalt, from midway between Rokeby and Bellerive. *Analyst*: W. St. C. Manson.

A. Limburgite, No. 3 Quarry, Woodend, Victoria (Newer Volcanic Series). (*Bull. Geol. Surv. Vic.*, No. 24, p. 28, 1912.)

2. Iddingsitized nepheline-basanite, One Tree Point, Sandy Bay, Hobart. (Aurousseau 1926.)
3. Limburgite, Llewellyn, near Avoca. *Analyst*: W. St. C. Manson.
4. Olivine-nephelinite, top flow at Derby (road cutting). *Analyst*: W. St. C. Manson.
5. Melilite-basalt, Shannon Tier. (Paul 1906, p. 305.)
6. Monticellite-nepheline-basalt, Shannon Tier. (*Ibid.*, p. 312.)
7. Melilite-fasinite, Shannon Tier. (Erdmannsdorffer 1928.)
8. Melilite from the melilite-basalt (No. 5) of Shannon Tier. (Paul 1906, p. 305.)

In addition to these specimens in which the olivine is more or less completely iddingsitized, there are occasional occurrences of this type of basalt in the Midlands and in northern Tasmania, in which the olivine is unaltered.

A specimen of the rock occurring about midway between Rokeby and Bellerive, adjacent to the road, was selected as representative, and analysed. The analysis (Table 6, No. 1) shows that for a basalt with so sodic a felspar, the composition is unusual. The high Fe_2O_3 content reflects the abundant iddingsite. The general resemblance to Analysis No. 2 of Table 6 suggests close relationship to the iddingsitized nepheline-basanite of Sandy Bay. The Rokeby basalt is slightly the richer in silica and alumina, and distinctly richer in magnesia; but it is poorer in lime and soda, and particularly in potash. There is also some resemblance to the limburgite from Llewellyn, near Avoca (Table 6, No. 3), but this is a more basic rock, with less silica and alumina, and much more magnesia than the Rokeby basalt. It would appear that the Rokeby basalts represent an intermediate stage in the differentiation of these basic and ultrabasic types. The nearest match in chemical composition is provided by a limburgite from Woodend in Victoria (Table 6, Analysis A).

Limburgites and Limburgite-basalts

Limburgite has been recorded from the vicinity of Burnie,[23] and further occurrences were found during this study at Llewellyn, near Avoca, at a point 20 miles south of Somerset, about seven miles south of Burnie on the road to Ridgely, at the northern end of the Green Hills on the Stanley Peninsula, and about eight miles west of Smithton.

These rocks consist of microphenocrysts of olivine, generally fresh, and frequently idiomorphic, in an extremely fine-grained groundmass of minute prisms of brown pyroxene, uniformly distributed granules or octahedra of iron ore, and a considerable amount of glass. Occasional microlites of felspar are present, and in some sections there are crystals in the groundmass which show very low double refraction, and appear to be nepheline.

The specimen from Llewellyn was analysed with results shown in Table 6, No. 3. The distinctive features of the analysis are the high magnesia figure, and the high soda, indicating a close relationship with the olivine-nephelinites (Table 6, No. 4) and with the melilite-basalts of Shannon Tier (Table 6, No. 5).

Rocks closely resembling the limburgites, but which are better called limburgite-basalts, because they contain a small proportion of plagioclase microlites, have been found at a number of localities: two and a half miles from Forth on the Forth-Wilmot road; at Rosebery; New Norfolk; near Castra; four miles from Ulverstone on the road to Castra; at Interlaken; on Flinty Top, near Oatlands; and at Don Heads.

In these rocks the pyroxene occasionally occurs as idiomorphic microphenocrysts, while in the rocks from Don Heads the occasional felspar crystals are unusually large. Flow structure is present in the Interlaken and Ridgely specimens, and the specimen from Flinty Top contains an inclusion of dolerite.

Olivine-nephelinites and Basanites

Nepheline-basanites occur at One Tree Point, Sandy Bay near Hobart, and at the Nipples, west of Anthill Ponds, in the Midlands; olivine-nephelinites outcrop at the Old Man's Head, near Lake Crescent, on Flat Top, near Oatlands, as the upper and middle lava flows at the Briseis mine, Derby, and near Ledgerwood and

Branxholm, where they form extensive flows filling the old Ringarooma Valley, at Scottsdale, and on the west side of the Forth Gorge, about two miles from Wilmot on the road to Sheffield.

The Sandy Bay rock was first described as a fayalite-basalt,[26] but was later shown to be a nepheline-basanite in which the olivine had been altered to iddingsite.[1] The earlier analysis of White and McLeod[26] is inaccurate, and is not quoted. The later analysis of Aurousseau[1] is shown in Table 6, No. 2. The general resemblance of this analysis to that of the melilite-fasinite of Shannon Tier (Table 6, No. 7) is evident.

The olivine-nephelinites vary somewhat in grain size, but are all fine-grained, and they have a distinctive texture in thin section (Pl. III, fig. 1). They consist of microphenocrysts of olivine, sometimes partially or completely replaced by iddingsite, set in a felted groundmass of short prisms of greenish to brownish pyroxene, small olivine grains, numerous relatively coarse octahedra of iron ore, idiomorphic prisms of apatite, and an abundant mesostasis of nepheline or felspathoidal glass. In some sections the nepheline occurs as well-shaped crystals, uniformly distributed throughout the groundmass (Pl. III, fig. 2).

The olivine is present in crystals of two generations. It forms microphenocrysts about 0·1 mm. long, which are idiomorphic, with a tendency to be corroded. It also occurs as idiomorphic crystals, about 0·02 mm. diameter in the groundmass. The pyroxenes occur as prisms and needles with an extinction angle of about 45° parallel to the prism face, and are restricted to the groundmass, with an occasional phenocryst the size of the olivine crystals. In one section a corona of pyroxene prisms encloses a partially dissolved grain of quartz. The iron ores occur as rectangular or angular grains of a size comparable with the other groundmass constituents. Apatite occurs as fine needles in the felspathoidal base, and as prominent prisms larger than the pyroxene prisms.

In some sections there is an abundant mesostasis of colourless glass, interspersed with crystals of nepheline. In others the glass is largely replaced by nepheline, which in some occurs as idiomorphic crystals. This is particularly so in the specimens from the Forth Gorge, Scottsdale and the top flow at Derby.

The latter rock was selected as typical, and an analysis made of it (Table 6, No. 4). Comparison with the other analyses of Table 6 reveals its close affinities with the limburgites and the melilite-basalts of Shannon Tier.

Melilite-fasinite

An occurrence of melilite-fasinite at Shannon Tier has been described by Erdmannsdorfer and Nieland,[9] and from thin sections of the Mines Department of Tasmania it would appear that it came from the hill known as the Beehive. The fasinite is a coarse-grained rock, consisting of laths of black pyroxene up to 2 cm. long, in a grey-white zeolite-bearing groundmass. The pyroxene is a brown titanaugite, with corroded cores of colourless augite, and rims of deep-green aegirine-augite. It contains inclusions of magnetite, apatite, olivine, nepheline, melilite and perofskite. The olivine is optically positive and has a composition about Fa_{17}. It occurs as occasional rounded grains about 2 mm. across, and shows partial alteration to serpentine, iddingsite and chlorite. The melilite occurs as grains and tablets about 3 mm. across. It is uniaxial, negative, with refractive indices $\omega = 1{\cdot}632$, $\epsilon = 1{\cdot}623$, and is yellow with weak pleochroism. It is idiomorphic against the enclosing pyroxene. Some of the melilite is altered to a greenish serpentine-like substance. Perofskite and apatite occur in some abundance, the

latter in prisms up to 2 mm. long. There are also subordinate amounts of red-brown biotite, a soda-hornblende, tentatively identified as lavenite, rohnite(?) and cancrinite.

The remainder of the rock, the groundmass, consists of zeolites, chiefly hydronephelite, and natrolite, with minor amounts of thomsonite, phillipsite and desmine, derived from the alteration of nepheline.

It seems likely from the description that this rock is a 'pegmatite' in a somewhat finer-grained melilite-fasinite, of generally similar composition. The analysis of the finer-grained melilite-fasinite is quoted in Table 6, No. 7. The general resemblance of the analysis to that of the nepheline-basanite from Sandy Bay (Table 6, No. 2), as distinct from that of the olivine-nephelinite (No. 4), agrees with Lacroix's[16] contention that the fasinites are to be correlated with the basinites—'La forme microlitique de la fasinite serait une basanite tres riche en nepheline.' Johannsen[11] relates them to the monchiquites, but this is not borne out by the limburgite analysis (No. 3).

It may be noted that R. A. Daly[2] mistakenly refers to this rock as a plütonic rock.

Melilite-basalts

Several small plugs of melilite-basalts and related rocks occur on Shannon Tier. Paul[20] in 1906 described a melilite-nepheline-basalt and a nepheline-eudialyte-basalt from this locality. Tilley[22] in 1928 re-examined the latter, and reported that the identification of eudialyte was incorrect. He also established that the unidentified mineral reported by Paul as probable Ca_2SiO_4, and previously referred to by Tilley[21] as 'shannonite,' was in fact monticellite, $(CaMg)_2SiO_4$, so that he renamed the rock a monticellite-nepheline-basalt.

Melilite-nepheline-basalt forms the small plugs known as the Ant Hill and the Beehive. It is a dense greenish-black rock showing phenocrysts of olivine. It has a granular hypidiomorphic texture and consists of olivine, pyroxene, melilite, nepheline, perofskite and magnetite. The olivine occurs as small idiomorphic phenocrysts, but is relatively inconspicuous compared with the melilite, which forms numerous elongated tabular or prismatic crystals ramifying the rock (Pl. III, figs. 3, 4). It is optically negative, with straight extinction, and is studded with minute inclusions of magnetite, perofskite and pyroxene. Paul separated some of the melilite, using Thoulet's solution, and had an analysis made of the acid-soluble portion of the powder, thus rejecting the included minerals other than apatite. This analysis is shown in Table 6, No. 8.

The pyroxene occurs only as small sparsely distributed prisms. The perofskite occurs as irregular, late-formed grains of a reddish-yellow colour, with anomalous double refraction. Nepheline is present as quadrate and hexagonal sections in some abundance (Pl. III, fig. 4) and there is a considerable amount of coarsely crystalline apatite and magnetite. Paul's analysis of this rock is shown in Table 6, No. 5, and reveals its close resemblance to the olivine-nephelinites and the limburgites.

The monticellite-nepheline-basalt is a fine-grained, hypidiomorphic granular rock, consisting of olivine, monticellite, nepheline, titanaugite, perofskite, apatite, magnetite, (?)sodalite, and colourless mica partly altered to chlorite. The monticellite occurs as rims (chadakrysts) around cores of olivine (oikakrysts). The pyroxene is more abundant than in the melilite-basalt, as in the perofskite, and both are coarser-grained. An analysis of this rock, presented by Paul, is shown in Table 6, No. 6. It shows that it is distinctly richer in alumina and lime and poorer

in magnesia and titania, and in alkalies, than the melilite-basalt. Except as regards titania, its resemblance is towards the melilite-fasinite, so that it lies more or less intermediate between the two.

Conclusions

This study indicates that the Cainozoic basalts of Tasmania are all olivine-basalts, ranging in composition between two extremes—

(a) a group of basalts with about 44 per cent SiO_2, 14 per cent Al_2O_3, and MgO:CaO about 11:9, namely the *titanaugite basalts,* which correspond to the olivine-basalt magma type, as defined by Kennedy,[14] being, if anything, more basic than it;

(b) a group of basalts with about 50 to 51 per cent SIO_2, 14 to 15 per cent Al_2O_3, and MgO:CaO about 8:8·5, namely the *basalts with black glass,* which are intermediate in composition between the olivine-basalt magma type and the tholeiitic magma type, as defined by Kennedy.[14]

Intermediate between these two extremes is a widespread group of *basalts with green glass* (group c).

As may be seen from Table 7, there is a considerable resemblance between the titanaugite basalts of group (a) and the Older Volcanic Magma Type of Victoria, on the one hand, and between the basalts with black glass (group (b)), and the Newer Volcanic Magma Type of Victoria, on the other, the latter resemblance being the closer. The group (c) basalts also have their counterparts in the widespread Trentham basalts of the Newer Volcanic Series of Victoria, and in the Flinders Type of the Older Volcanic Series in that State. However, despite the tholeiitic affinities of the group (b) basalts, there is a clear distinction both in chemical and mineralogical composition between the various olivine-basalts and the Mesozoic dolerite magma of Tasmania, which was truly tholeiitic.[7]

TABLE 7

Basaltic Magma Types in Tasmania and Victoria

	Tasmanian Magma Types			*Victorian Magma Types*	
	Olivine titanaugite-basalt Type	Olivine-augite-basalt Type	Dolerite Magma Type	Older Volcanic Magma Type	Newer Volcanic Magma Type
SiO_2	44	50	52·5	46	50
Al_2O_3	14	14·5	16·2	15·5	15
FeO, Fe_2O_3	12·0	11·5	8·7	11·5	11·5
MgO	11	8	6·6	8	8·5
CaO	9	8·5	11·3	8	8·5
Na_2O	2·6	2·6	1·6	2·9	3.0
K_2O	1·2	0·7	0·9	1·4	1·2

In Victoria, titanaugite-basalts are sufficiently characteristic of the Older Volcanic Series to serve as 'markers,'[4] and the iddingsite-basalts with black glass (Footscray and Malmsbury Types) are equally characteristic of the Newer Volcanic Series. The basalts with green glass in the two series match too closely to permit their classification as Older or Newer Volcanic on petrological grounds, and can be

classed only according to their association with more characteristic types of basalt, or on stratigraphic evidence. Such a relation does not hold in Tasmania.

Fig. 1 shows the approximate localities of the specimens studied in terms of the main basalt types, and hence the relative distribution of these main types, assuming that the sampling has been adequately random. The map reveals some intermingling of types, but it also shows:

(a) a predominant association of titanaugite basalts (Hampshire, Burnie, Deloraine, Branxholm types) and basalts with green glass (Mersey, Waratah types) in the north-central and north-western areas;

(ii) a predominance of basalts with black glass (Midlands, Bridgewater, Ouse types) extending from Launceston through the Midlands (strongest development) to the south-east;

(iii) a small association of basic oligoclase-basalts intermingled with (ii) in the south-east.

The olivine-nephelinites are associated with titanaugite basalts at Forth, Scottsdale, Ledgerwood and Derby, and, together with limburgites, nepheline-basanites and melilite-basalts, accompany the basalts with black glass in the Midlands and south-east.

It thus appears, on petrological grounds alone, that in Tasmania either (a) there were, as in Victoria, two major periods of basaltic volcanicity, deriving from source magmas of different composition, which gave rise to petrologically distinct basaltic types, or (b) that contemporaneous extrusions developed from two or more co-existent basaltic magmas, occurring either in separate reservoirs or as layered magma differentiated within a single magma reservoir of considerable dimensions.

The distribution of the basalt types relative to one another, and to sediments of known age, such as the Miocene beds at Wynyard, and the Launceston and Derwent Basins, favours the second alternative. In this connection the relationships of the basalts in the area between Breadalbane, Perth and Evandale to the sediments of the Launceston Basin is critical. These basalts include typical titanaugite basalts, as at Perth, and if, as appears, they overlie the Miocene sediments, then some at least of the titanaugite basalts are post-Miocene. Basalts of the Midlands Type at St. Leonards and near Nile are definitely younger than these sediments, and the Bridgewater and Ouse basalts are younger than similar sediments in the Derwent Basin. Petrological studies, therefore, provide no criteria for distinguishing between pre-Miocene and post-Miocene (Pliocene) basalts in Tasmania. They do, however, indicate the more or less contemporaneous existence of the two extreme basalt magmas in close proximity to one another.

Relationship between Tertiary Basalts and Jurassic Dolerites

A comparison of the distribution of the Tertiary basalts and the Jurassic dolerites shows that the basaltic magma must have underlain almost the same area as the dolerite magma, or possibly a wider area, since basalts occur on Flinders Island, although the volume of basalt extruded was probably less than one-quarter the volume of dolerite magma drawn off from its source reservoir. In each period, therefore, a more or less continuous sheet or body of magma underlay an area of the order of 15,000 square miles; and unless it is assumed that the dolerite intrusions completely drained their source reservoir, some layered arrangement in depth of the two magmas must be pictured.

These crustal layers must normally be solid. If they were fluid, the tholeiitic layer would need to be uppermost in Jurassic time, to permit the intrusion of so homogeneous a tholeiitic magma as the dolerite, on so wide a scale; and a fluid layering with tholeiitic magma at the top is not compatible with the early extrusion of olivine-basalt magma in the Tertiary.

These successive periods of igneous activity must have resulted, therefore, from the melting of sheets of these crustal layers. The probability is that the tholeiitic layer overlies the olivine-basalt layer, and that the vigorous erosion that followed the dolerite intrusions was accompanied by an isostatic adjustment that by Tertiary time had raised the tholeiitic layer above the critical level for melting, so that it remained solid while the deeper-lying olivine-basalt layer melted. The more or less contemporaneous extrusion in Tertiary times of undersaturated olivine-basalt, and olivine-basalt with tholeiitic affinities, together with intermediate types points to a gradational layering in the olivine-basalt layer of the crust, presumably an upward transition to the tholeiite layer.

There is a parallel between this picture and the crustal layer hypothesis evolved by Kennedy and Anderson[15] and recently invoked by MacGregor[17] to explain the sequence of extrusions during the Carboniferous-Permian volcanicity in Scotland. They postulate that basaltic rocks originate from sheet-like reservoirs of fluid magma almost constant in depth, and extending for long distances, in many instances hundreds of miles, at certain critical levels in the earth's crust. The reservoirs are pictured as originating at different times and at different levels by the fusion of crustal layers of different composition, distributed as indicated in Fig. 2. The tholeiitic layer is thought to result, possibly, from contamination of original alkaline olivine-basalt magma by the granitic layer.

Crustal Layering in a Non-Orogenic Region
(after MacGregor (1948))

Granitic Layer (11 km.)		Essentially homogeneous
Upper Intermediate Layer (18 km.)	Tholeiitic (olivine-free or olivine-poor) basalt	Essentially homogeneous
Lower Intermediate Layer (6 km.)	Alkaline olivine-basalt	Graded: more mafic downwards
Lower Layer	Ultrabasic rock	

FIG. 2.

Significance of Green and Black Glasses

The association of green glass with undersaturated olivine-basalts, and of black glass—that is, glass carrying innumerable globules and trichytes of iron ore—with basalts showing tholeiitic affinities, does not appear to be fortuitous. Similar associations are found in the basalts of the Newer and Older Volcanic Series in Victoria, and tholeiites proper are characterized by such black glass. It is a feature of tholeiites that they show a higher FeO/MgO ratio than olivine-basalts; and it would appear that the increased relative proportion of iron is not wholly accommodated in the normal ferromagnesian silicates, but tends to accumulate to some extent in the residual magma, in other words the glass. Black glass, then, is probably an indication of strong tholeiitic affinity, and may also be regarded as indicating that the basalt containing it is derived from a magma that has undergone some degree of differentiation, resulting from impoverishment in magnesia.

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Description of Plates

Plate I

Fig. 1.—Ouse Type, analysed specimen. ×20, ordinary light. Glassy basalt consisting of phenocrysts of olivine, which may be serpentized, and microphenocrysts of plagioclase, about the size of groundmass laths for a holocrystalline basalt, set in a black intersertal glass with radially arranged or plumose trichytes of augite.

Fig. 2.—Bridgewater Type, analysed specimen. ×20, ordinary light. Phenocrysts of olivine, in a groundmass of plagioclase laths, granular augite, and intersertal black glass. There is some tendency for the plagioclase to form occasional microphenocrysts.

Fig. 3.—Bridgewater Type. ×20, ordinary light. Phenocrysts of olivine in a groundmass of plagioclase laths, granular to prismatic augite, and black glass.

Fig. 4.—Midlands Type, analysed specimen. ×20, ordinary light. Shows typical texture, with abundant colourless to slightly brownish augite, sub-ophitic towards plagioclase laths (labradorite), and enclosing phenocrysts of olivine with rims of iddingsite. Iron ores tend to be lath-shaped, and a little dark glass may be present in the interstices. The rock tends to be vesicular.

Fig. 5.—Mersey Type, analysed specimen. ×20, ordinary light. A relatively coarse-grained example, with intergranular texture, and tending to contain more or less intersertal green glass. The groundmass of plagioclase laths, granular augite, iron ore and glass encloses phenocrysts of olivine, and occasional inchoate phenocrysts of augite and plagioclase.

Fig. 6.—Waratah Type, analysed specimen. ×11, ordinary light. Phenocrysts of olivine, augite and plagioclase in an intergranular to intersertal groundmass of labradorite laths, augite granules, iron ore, and green glass.

Plate II

Fig. 1.—Hampshire Type, analysed specimen. ×11, ordinary light. Characteristic coarse rosette of zoned titanaugite crystals, forming macrophenocrysts in an intergranular olivine-titanaugite-basalt.

Fig. 2.—Burnie Type, analysed specimen. ×20, ordinary light. Shows olivine phenocrysts, slightly resorbed, and a typical patch of ophitic titanaugite and plagioclase laths, with parallel arrangement from flowage. The lens-like shape of the ophitic titanaugite areas is particularly obvious with crossed nicols.

Fig. 3.—Deloraine Type. ×20, ordinary light. An olivine-titanaugite-basalt in which the olivine phenocrysts are more clustered than in the Burnie Type, and the ophitic titanaugite is gathered into larger crystals, with fewer and random oriented plagioclase laths, leaving larger and more prominent areas of colourless felspar laths between.

Fig. 4.—Branxholm Type. ×20, ordinary light. Microphenocrysts of olivine and labradorite in an intergranular groundmass that contains a high proportion of brown to violet augite, and a little coarsely crystalline magnetite. The abundance of augite in the groundmass gives the rock a dark appearance, even in thin section.

Fig. 5.—Branxholm Type. ×20, ordinary light. A coarse-grained variation, approaching an olivine-dolerite in texture, and consisting of phenocrysts of olivine and plagioclase in an intergranular groundmass of coarse plagioclase laths and coarse granules of brownish augite or titanaugite. In places the felspar is somewhat analcitized, and colourless glassy areas occur in which there is a little greenish chlorite and skeletal iron ore.

Fig. 6.—Rokeby Type, analysed specimen. Basic oligoclase-basalt, ×35, ordinary light. Shows microphenocrysts of olivine completely altered to iddingsite in a microlitic intergranular groundmass of oligoclase laths and augite.

Plate III

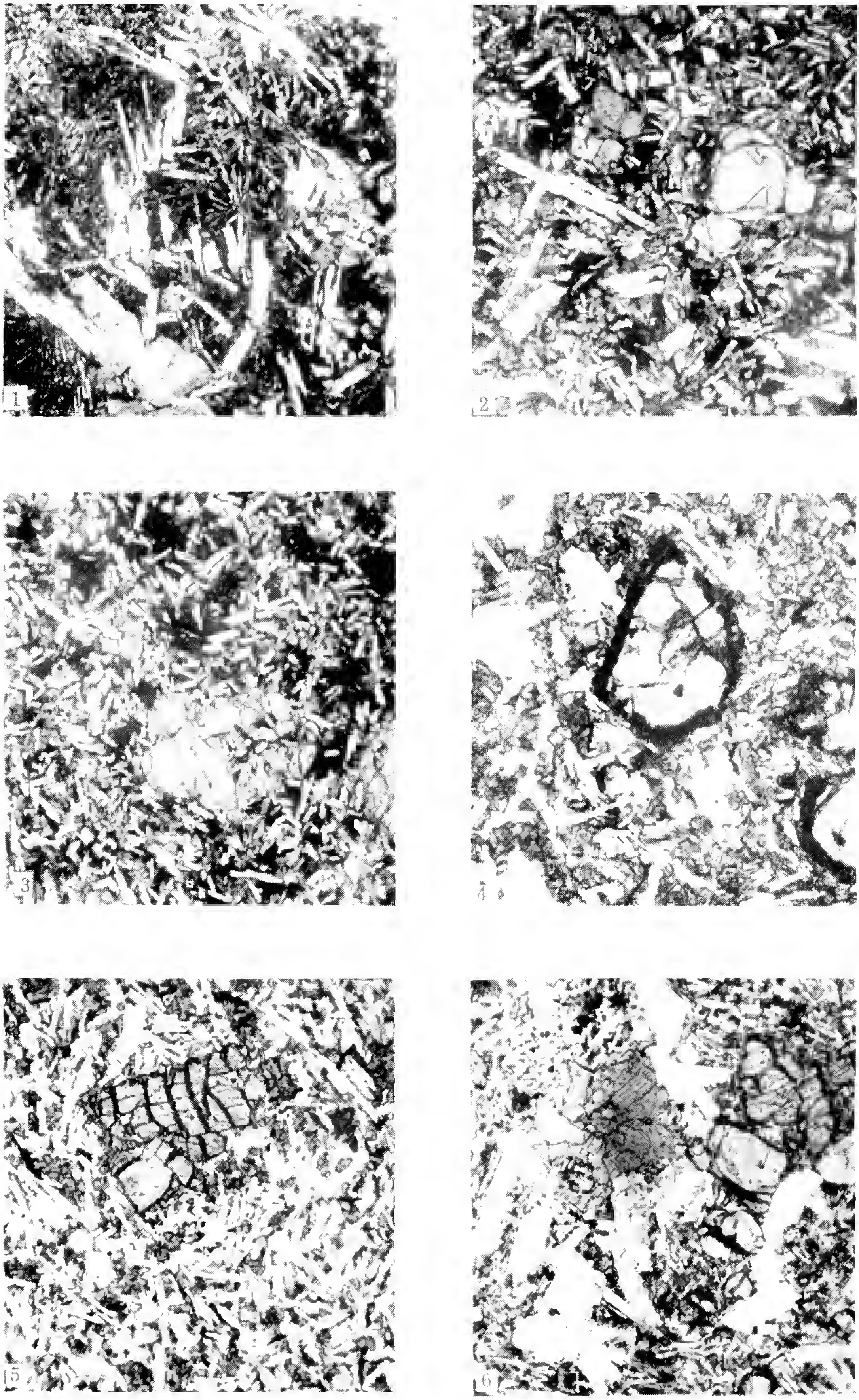
Fig. 1.—Olivine-nephelinite, analysed specimen. ×35, ordinary light. Typical texture of a fine-grained olivine-nephelinite, showing microphenocrysts of olivine in a groundmass of nepheline crystals, micro-prisms of greenish to colourless augite, and squarish grains of iron ore.

Fig. 2.—Olivine-nephelinite, analysed specimen. ×135, ordinary light. Central part of field of Photo. 16, magnified to show the texture of the groundmass, and the inclusions in the nepheline crystals.

Fig. 3.—Melilite-basalt. ×35, crossed nicols. Shows two bladed crystals of melilite, with numerous small inclusions, and phenocrysts of pyroxene in an intergranular groundmass.

Fig. 4.—Melilite-basalt. ×35, ordinary light. Same field of view as Fig. 3, showing the abundant nepheline and granular iron ore in the groundmass. (Note that Fig. 4 has been inadvertently rotated during mounting.)

Fig. 5.—Point of eruption, about one mile north of the Hampshire Railway Station, and just east of the railway line. The flow issued to the south-west. This is the type locality of the Hampshire Type olivine-basalt.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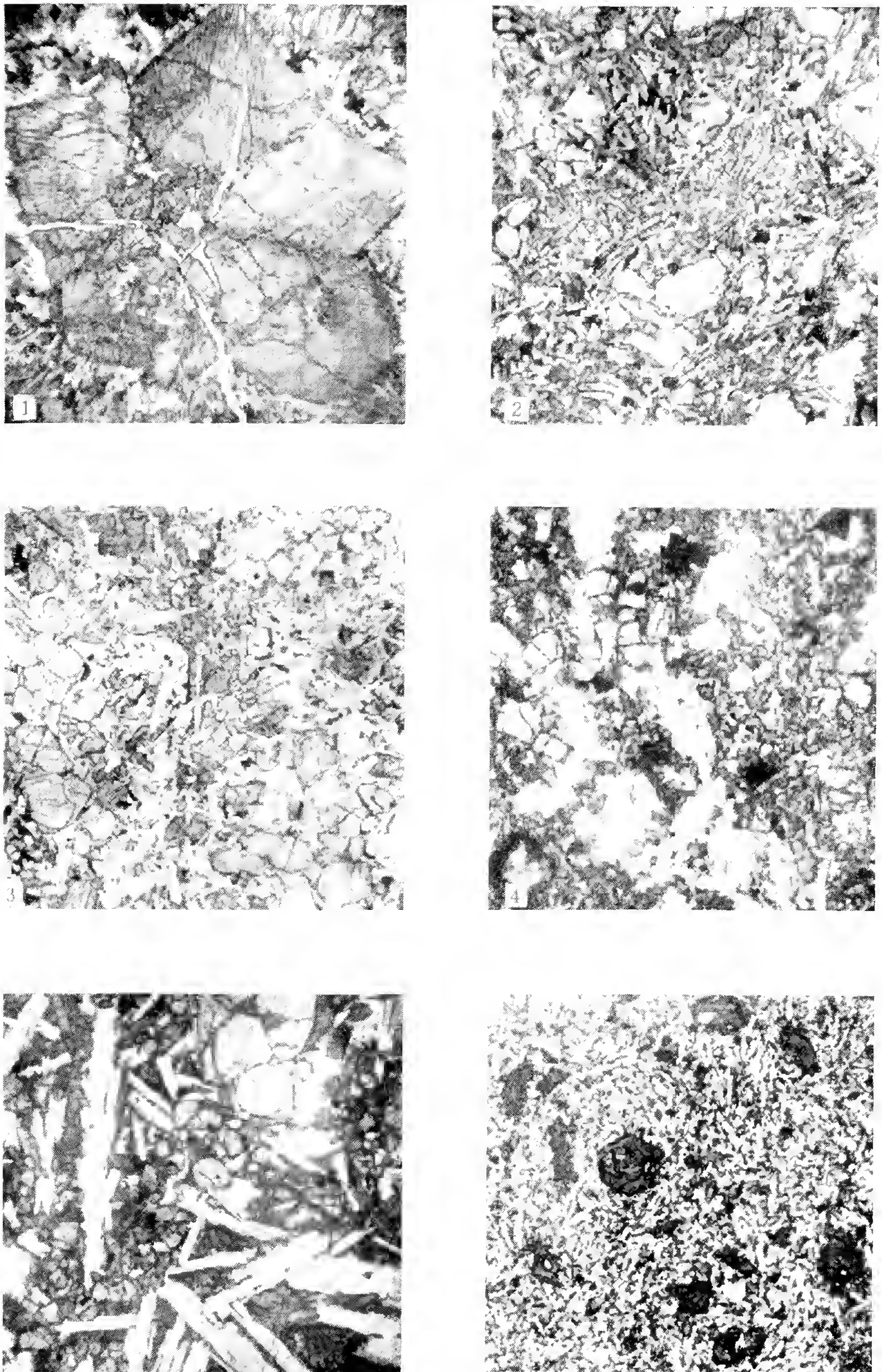
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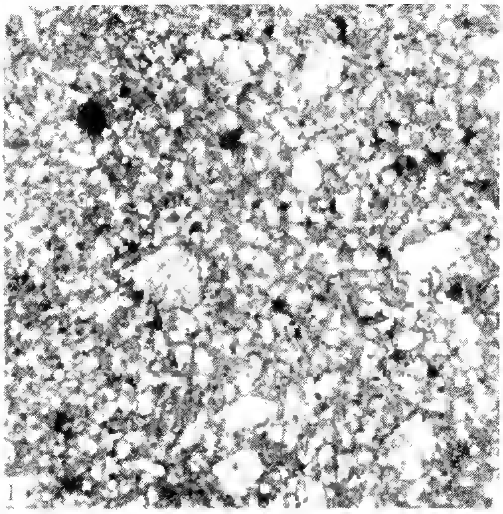
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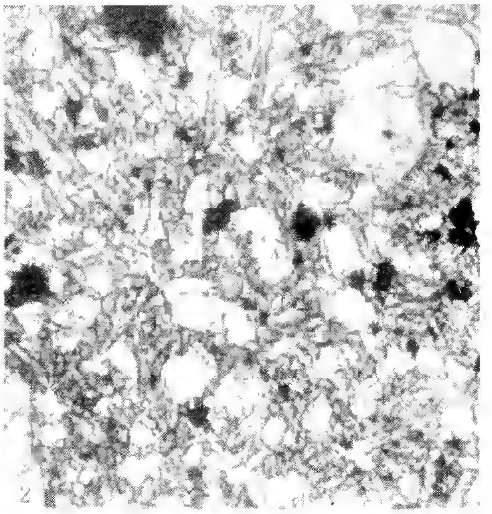
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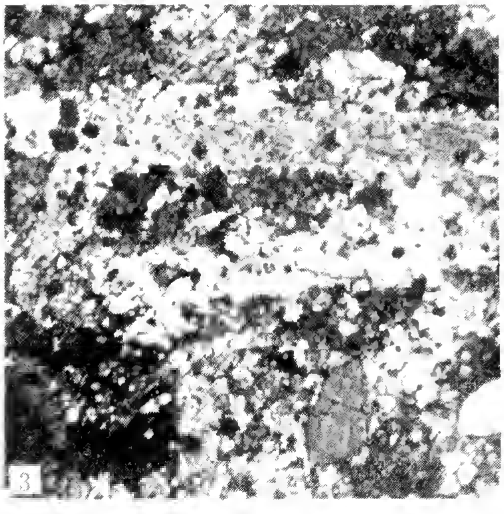
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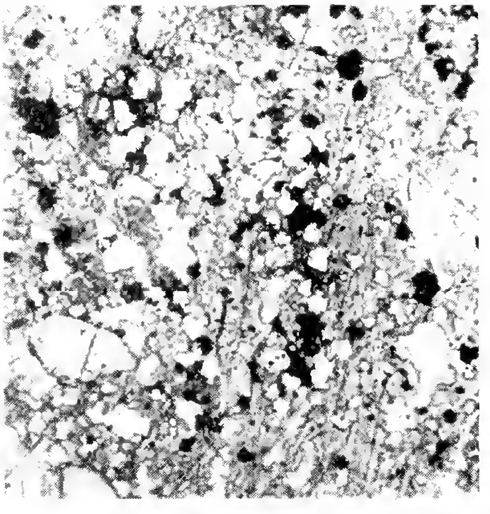
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GEOLOGY OF PICNIC POINT, PORT PHILLIP BAY, VICTORIA

By Edmund D. Gill, B.A., B.D.*

[Read 14 July 1949]

Summary

Evidence for an emerged shore platform and an emerged shell bed or emerged beach at Picnic Point is described. The platform is in ferruginous sands often called 'Red Beds.' The partially cemented sands are shown to be horizontal, and conformable with the underlying ironstones, the presence of which determines the occurrence of the Point. Aboriginal kitchen middens consisting chiefly of *Mytilus* occur on the cliff tops. A collection of shells made from the emerged beach deposits before they were disturbed is listed.

Introduction

Discussion has taken place from time to time as to whether the shell beds at Picnic Point, Hampton, on Port Phillip Bay, are aboriginal kitchen middens, emerged shell beds, or both, and what their relationships are to the associated rocks. As active marine erosion is taking place, and harbour works were being effected, it was thought expedient to collect all available evidence. The results are also of some interest for studies in eustatic sea levels.

Picnic Point

Earlier Work

As long ago as 1854 and 1856, Selwyn in his reports on the geology of the Colony of Victoria (as it was then) referred to the shell beds round Port Phillip. Then Hart in 1893 gave a more detailed account of the rocks on the north-east side of Port Phillip, and described an emerged shell bed at Picnic Point 'a few feet above the present water level at its highest part'; Hall and Pritchard (1897, p. 225) questioned this. In 1909 Pritchard (p. 22) noted that earlier writers had often confused emerged shell beds with aboriginal kitchen middens, and named Hampton (i.e., Picnic Point) as one of the well-known localities where he claimed this confusion had taken place.

Later, Chapman (1929, p. 122) drew attention to the Picnic Point deposits and claimed that both kitchen middens and emerged shell beds were present there, stating that 'We may reasonably assume that these (the emerged shell beds) do not belong to the mounds (kitchen middens) above, as they consist of myriads of small shells, of no use to the aborigines for food, though mixed with larger, edible kinds; moreover, this lower bed is free from charcoal.' Chapman reproduced two photographs (figs. 45, 46) of the 'raised beach,' which was vegetated at that time.

Keble and Macpherson (1946, pp. 61-64) also expressed the opinion that shell beds and kitchen midden are both present, stating that 'At Hampton the wave platform which appears to have been formed on a raised beach is 23 feet above L.W.M., but there is evidence of a small amount of tectonic uplift since it was formed. It is covered with comminuted shells, mainly mussels, which may belong to the period of eustatic rise of sea level, or, as some maintain, to human agency, the

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platform showing evidence of having been the site of an aboriginal kitchen midden. Thirty or more species of mollusca, some marine worms, and a coral—all littoral species—are definitely associated with the formation of the raised beach.' The 'raised platform' of these authors is the top of the cliff 23 feet above L.W.M., and not the emerged platform shown in Fig. 1. The shell beds on the top of the cliffs are kitchen middens. The marine fauna mentioned is that collected by Hart when he was studying that shoreline, and it is now in the National Museum, Melbourne. It does not come from 23 feet above L.W.M., but, to use Hart's own words (1893, p. 158), from 'a few feet above the present water level at its highest part,' or as Chapman stated it, 'about 8 ft. above high-water mark' (caption of Fig. 46).

Origin of Picnic Point

The Point is present because of the protection afforded the shore by a hard, dark-brown, ferruginous sandstone. Similar ironstones occur at intervals along the shore, and are well developed, for instance, at Brighton Beach to the north, and Rickett's Point to the south. Smaller outcrops occur at close intervals all along the bayside. The occurrences have been explained by assuming a continuous ironstone bed which is flexed upwards in low folds to form small headlands like Picnic Point and Rickett's Point. This interpretation is considered unsatisfactory because (1) it does not account for the intervening smaller outcrops; (2) current bedding in the cliff at the Point shows the beds are horizontal; and (3) no evidence of dip in the ironstones can be found.

Because the higher beds in the cliff at Picnic Point are horizontal, the underlying ironstone could only be warped if there were an unconformity between the ironstone and the sands and gravels above. Indeed this was claimed by Hart (1893, p. 157). The top of the ironstone is irregular, and this may be why he assumed it was eroded. Hall and Pritchard (1897, p. 190) interpreted Hart's 'unconformities' as localized examples of cross-bedding. Just south of the actual Point at Hampton there are some dips of 1° to 2° which are so interpreted. Recent erosion at Picnic Point has cut in behind the ironstone, and it reveals that the irregular upper surface of the ironstone is due to irregularities of cementation by ferruginous matter. A light-grey clayey sand is seen to lie behind and partly underneath the ironstone, penetrating irregularly into it. The clayey sand is continuous with the cliff material and there is no sign of any break in sedimentation, i.e., no diastem or disconformity, much less an unconformity. A close parallel to the relationships existing between the clayey sand and the ironstone can be seen in a number of places in the present cliff face where there is secondary cementation with ferruginous matter, although the process has not gone as far as in the ironstone. The ferruginous depositions have stained and cemented the sands of the cliff, but in such a way as to leave pockets of unstained and uncemented sediments so that the two types of rock interpenetrate considerably.

It is therefore inferred that the ironstone bed is not a separate stratigraphical unit, but is conformable with the sands above. The ironstone is merely a more highly ferruginous phase of the same sediments. It has been noted that the ironstones occur at depositional base levels, for instance on top of the Older Basalt at Royal Park and West Essendon, and at water level along the bayside.

Age of the Ironstones

No fossils have been found in the ironstones or sands at Picnic Point by the writer, but Hall and Pritchard (1897, p. 202) record finding some, although a list

was not given. However, 300 yards south of the Brighton Pier, fossils were found in a similar ironstone by Mr. F. A. Cudmore before this locality was covered during foreshore improvements. Mr. Cudmore's collection, now in the National Museum, includes:

GASTEROPODA	*Leiopyrga quadricingulata* Tate (common)
LAMELLIBRANCHIATA	*Tellina albinoides* Tate
SCAPHOPODA	*Dentalium* sp.

Recently Mr. A. A. Baker discovered a small pocket of fossils in ironstone on the shore 20 chains south from Black Rock point (on which is the pier), almost opposite Seaview Crescent, but a little south of it. A piece of this rock presented to the National Museum (Reg. No. 14680) contains the following fossils:

GASTEROPODA	*Leiopyrga quadricingulata* Tate
LAMELLIBRANCHIATA	*Donax depressa* Tate
	Nuculana crassa (Hinds)

The determinations from the above two localities were made by Mr. Cudmore and the writer, and the age is believed to be Kalimnan (Lower Pliocene) although the evidence is not altogether conclusive. However, *Leiopyrga quadricingulata* is a common fossil in the type Kalimnan beds, and Singleton (1941, p. 42) named *Nuculana crassa* as a fossil typical of the upper shell bed of the type section. In the National Museum there are specimens of *Donax depressa* (Reg. No. 12789) and *Tellina albinelloides* (Reg. No. 12788) preserved in a ferruginous sandstone similar to that of the Port Phillip area (i.e., a similar facies) from Boggy Creek, near Bairnsdale, where beds of Kalimnan age occur.

The ironstone beds at Rickett's Point, four miles S.S.E. of Picnic Point, are mapped as Cheltenhamian (Upper Miocene) by Singleton (1941), while the lower beds at Royal Park and the ironstones at Keilor are stated to be Balcombian (Middle Miocene). So it would appear that the ironstones, although of similar lithology and occurring in similar circumstances in the Port Phillip area, are not of the same age.

EMERGED SHORE PLATFORM

On the south side of Picnic Point, erosion has shown a shore platform cut behind the ironstone beds in soft clayey sands (Fig. 1). The platform is 28 feet wide, and is 15 inches higher at the edge of the former sea cliff than it is at the

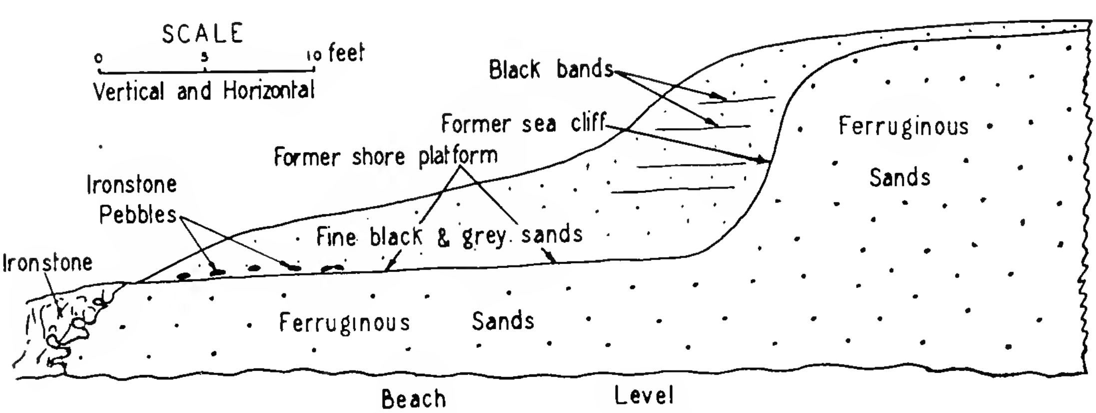

FIG. 1.—Cliff section on south side of Picnic Point, Hampton, exposed by marine erosion.

seaward edge. The latter is 8·5 feet above Admiralty datum (M.L.W.S.; see Fairbridge and Gill 1947). Active erosion has been progressing of recent years during which the platform has been under observation, with the result that it is clear that a true platform is present, i.e., the section line is not a random cliff section simulating a platform. The platform is on a relatively stable part of Port Phillip, being west of Selwyn's Fault and the Bellarine hinge-fault (Keble 1946).

At a number of places round the shores of Port Phillip Bay there are low platforms in front of former sea cliffs. The nearest to Picnic Point is that at Brighton Beach, where a wide platform extends in front of a cliff which is about 20 feet high at the highest part. A hole was sunk in the platform 25 feet seawards from the highest part of the cliff, and this penetrated three feet of fine grey (apparently aeolian) sand of the type found generally on top of the 'Red Beds,' then met the coarse red poorly-sorted and more compacted grits of the above formation. The material was compared with that in the adjacent cliff, and was found to be almost identical.

At Picnic Point ironstone pebbles occur on the seaward end of the emerged shore platform, and coarse sand marks the junction of the landward end. Above these are grey and black fine, well-rounded, siliceous sands such as cover the general terrain of this area, and the same as found on the Brighton platform. There is no real stratification in these sands at Picnic Point, but five thin darker bands noted in the landward end of the section are interpreted as former vegetated surfaces, or at least as surfaces on which organic matter gathered.

It is thought that after the recession of the sea from the platform the fine sand blew from the cliff above and gradually covered the platform, assisted by the usual gravitational drift from the higher to the lower areas. The dark bands in the sands may represent stages in the building up of the deposits on the platform.

In the present state of our knowledge of the Port Phillip area, it is not known to what extent eustatic and/or tectonic factors are responsible for the emergence of this platform.

Clubhouse Section

On the north side of Picnic Point, a large area has been planated for the accommodation of the boats and clubhouse of the Sandringham Yacht Club. A retaining wall was built and then the cliff excavated to fill in along the wall, and to extend the chosen level landwards. Near the Point, a section is to be seen beside the clubhouse as shown in Fig. 2. There the ferruginous sands constitute an old sea cliff which is covered with a drift of grey sand and with midden material. Following the angle of the former cliff there occurs in the sands a dark line of charcoal and broken *Mytilus* shells, some burnt, such as can be seen in the middens still on the tops of the cliffs in this area. The middens consist almost entirely of *Mytilus,* which still occurs in large numbers in the waters round the Point. Occasional *Haliotis, Turbo,* and *Ostraea* are found in the middens, but these are the exceptions and *Mytilus* the rule.

At the base of the seaward part of the section are ironstone pebbles up to three inches in diameter, distributed horizontally. In close proximity to these were found marine shells which had clearly been worn on a beach—*Katelysia, Ostraea, Mytilus, Arca, Austrocochlea,* and some minute gasteropods. The calcareous tubes of the marine worm *Serpula* were also present. The shells found in middens are of edible types and sizes, and they are not worn, because they have been gathered alive from the water. Of the shells named above, a number were not edible species

or edible sizes, and, being worn, they could not have been carried ashore for food by aborigines.

Above the horizon just described was a layer of charcoal with broken and burnt shells, viz., the remains of a midden. Whether this represented a midden on the old 'raised beach' or comminuted material transported from the middens on the top of the cliff could not be determined with certainty, but in view of the thinness of the deposit the latter is thought to be the more likely explanation.

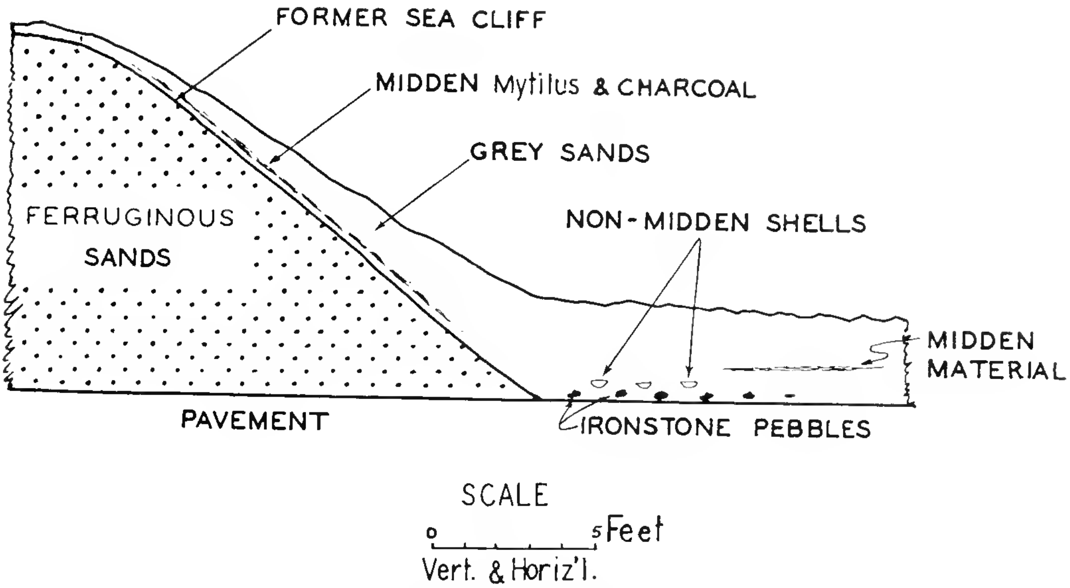

FIG. 2.—Section is cutting made to accommodate the Sandringham Yacht Club clubhouse on the north side of Picnic Point, Hampton.

On the Point side of the section just described is a slope of grey sand in which there are numerous shells. In an effort to determine the nature of this deposit, and to discover whether it is *in situ* or not, a hole was carefully sunk 15 feet from the clubhouse towards the Point. Samples of sand were taken, and fossils carefully collected to a depth of over three feet, where two pieces of broken glass were found! This proved, of course, that the material was not *in situ*; it was probably thrown there during the excavation to accommodate the clubhouse building. Although no inference can be made concerning the position of this material, inferences can be made relative to its composition. The majority of the shells were not of edible kinds, and many of them were worn, indicating that they had been subjected to abrasion on the beach. Further, they were all through the sand, and not just on the surface as would be the case with shells carried by picnickers from the present beach. Also, as one ascends the slope these shells become more and more scarce, and no such deposits are found on the tops of the cliffs. The cliff-top shells all belong to the middens, there being no emerged shell bed or beach there. Middens are commonly on the higher points, as no doubt the aborigines wanted to see what was happening, and also to guard against surprise.

Emerged Shell Bed Fauna

In the National Museum, Melbourne, there is a collection of fossils from 'Raised Beach, Picnic Point, Hampton,' presented by Mr. T. S. Hart on 20/1/04. The fossils are significant in that they were collected by an experienced observer before the Point was disturbed by the human activities and bayside erosion which now make its interpretation difficult. The collection comprises the following forms:

		Nat. Mus. Reg. Nos.
COELENTERATA	*Orbicella urvillei* Edwards and Haime	8679–8680
LAMELLIBRANCHIATA	*Amphidesma nitida* (Deshayes)	8700–8706
	Anadara trapezia (Deshayes)	8681
	Arca pistachia Lamarck	8684–8686
	Cardium racketti Donovan	8688
	Cleidothaerus albida Lamarck	8682, 10755
	Electromactra ovalina (Lamarck)	8691
	Eumarcia fumigata Sowerby	8644–8649
	Katelysia strigosa (Lamarck)	8689–8690
	Notovola fumatus (Reeve)	8683
	Ostraea sp.	8695
	Solen vaginoides Lamarck	8692–8693
	Soletellina biradiata (Wood)	8694
	Wallucina icterica (Reeve)	8687
GASTEROPODA	*Austrocochlea odontis* (Wood)	8714–8717
	Bembicium melanostoma (Gmelin)	8733–8735
	Cellana tramoserica Sowerby	8696–8697
	Cominella lineolata (Lamarck)	8737–8738
	Clanculus plebeius Phillips	8718–8723
	Haliotis ruber Leach	8707
	Herpetopoma baccatus (Menke)	8736
	Hypotrochus monachus (Crosse and Fischer)	8729–8732
	Mactcola anomala (Angas)	8742
	Parcanassa jonasi Dunker	8740
	P. pauperata (Lamarck)	8739
	Patelloida alticostata Angas	8698–8699
	Phasianella australis (Gmelin)	8711–8713
	Salinator fragilis (Lamarck)	8728
	Turbo undulatus Solander	8708–8710
	Uber conicum (Lamarck)	8724–8727
	Vermicularia sipho Lamarck	8741
	Zeacumantus cerithium (Quoy and Gaimard)	8743

I am indebted to Miss J. H. Macpherson, B.Sc., conchologist at the National Museum, for bringing the nomenclature of these shells up to date in accordance with a check list about to be published (Chapple and Macpherson 1950).

Conclusions

1. There is an emerged shore platform at Picnic Point, 8·5 feet above mean low water springs.
2. The ironstones and the uncemented parts of the 'Red Beds' interpenetrate at Picnic Point, and so must be conformable, no unconformity existing as previously suggested.
3. Current bedding shows that the deposits at the Point are horizontal, and so the Point was not formed by local warpings as has been suggested.
4. There are evidences of an emerged beach or shell bed at the Point, and this fits in with the evidence of the shore platform. However, the deposits have been

disturbed by human agency, and so written and photographic evidence predating this disturbance are used to assist interpretation.

5. Aboriginal kitchen middens consisting mostly of *Mytilus* and charcoal occur on the tops of the cliffs 23 to 27 feet above L.W.M., but there is no emerged shell bed there as has been claimed.

Acknowledgments

It is my pleasure to acknowledge assistance in the field from Mr. F. A. Cudmore, Honorary Worker in Palaeontology at the National Museum, and Mr. J. J. Jenkin, Museum Assistant.

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6

SOME 'SOOTY MOULDS' COLLECTED IN QUEENSLAND

By Eileen E. Fisher, Ph.D.*

[Read 13 October 1949]

Abstract

Setella halophila, a new species, is described; this constitutes the first record of the genus in Australia. *Chaetothyrium Citri* (Arn.) Fisher is recorded for the first time in Queensland. Both fungi belong to the Chaetothyriaceae and occur on *Aegiceras corniculatum* Blanco, a mangrove species, which excretes large quantities of salt.

A new variety, *Asterina systema-solare* Mass. var. *minor*, is described and compared with Rodway's type of *A. systema-solare* Mass., which is also re-described.

Bailey first collected *Meliola polytricha* K. & C. on *Callistemon*. After comparison of Bailey's specimen and others collected by me, with type-material of the species, the Queensland specimens are referred to a new variety, *M. polytricha* K. & C. var. *queenslandica*.

The 'sooty mould' fungi are plentiful in the districts surrounding Brisbane, and some collections have been made, which are worthy of record.

The species considered here represent three of the families classified in an earlier paper (Fisher 1939).

I. Chaetothyriaceae Th. emend. E. Fisher

Setella halophila sp. nov.

Hyphis brunneis septatis 3·5-7 μ diam., mycelium atrum membranaceum formantes. Ascocarpis globulis 60-100 μ diam., saepe ferentibus hyphales appendices setiformes 17·5-37·5 μ longas, aparaphysatis; ascis 30 μ x 10 μ, octosporis, evanescentibus. Ascosporis, brunneis, ellipticis, 3 - septatis, 10 - 12·5 μ longis, plerumque 11·25 μ, latis 3·75 μ, setis absentibus, ore pycnidii aliquid fimbriato. Pycnosporis hyalinis, ellipticis, non septatis, plerumque 5 μ longis, 2·5 μ latis. Conidiis sparse formatis, brunneis, fusiformibus, phragmoseptatis, 65 μ longis x 10 μ parte latissima. *Hab.*: In salso sudore in summis foliis *Aegiceras corniculati*. Southport, Queensland, Australia, August 1947.

Leg. R. F. Langdon. (Typus in Kew et in Herb. auct.)

Setella halophila n.sp. is described from a sooty mould occurring on the leaves of *Aegiceras corniculatum* Blanco, which was collected at Southport, on the Queensland coast, 47 miles south-east of Brisbane. *Aegiceras corniculatum* is a mangrove species, which excretes a large amount of salt through the leaves, thus providing a saline substratum for the mould. The epithet 'halophila' has therefore been chosen to denote the high saline tolerance of this fungus.

As is characteristic of the family *Chaetothyriaceae*, *S. halophila* forms a thin, membranous, sooty film, which may be readily separated from the surface of the host leaf. The mycelium consists of hyphae of two types. The more superficial hyphae are 5-7 μ diam., dark brown, septated and constricted at the septa, to form approximately isodiametric cells (Fig. 1, d). The hyphae which lie nearer to the surface of the leaf are narrower, approximately 3·5 μ diam., light brown, septated, but not constricted at the septa (Fig. 1, e).

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There is an abundant development of ascocarps. These are globular in shape, ranging from 60 μ to 100 μ diam. The wall of the ascocarp is dark and dense in structure; its surface may be smooth, but frequently bears 2-7 bristle-like, hyphal appendages, 17·5-37·5 μ in length (Fig. 1, f). Paraphyses are absent; the asci are 8-spored and measure 30 μ x 10 μ. The thin walls of the asci break down early, so that the mature ascospores are rarely found enclosed by the ascus; they are usually set free inside the ascocarp. The ascospores, which measure 10-12·5 μ (average 11·25 μ) in length, and 3·75 μ in width, are brown, elliptical, and divided into 4 cells by 3 transverse septa.

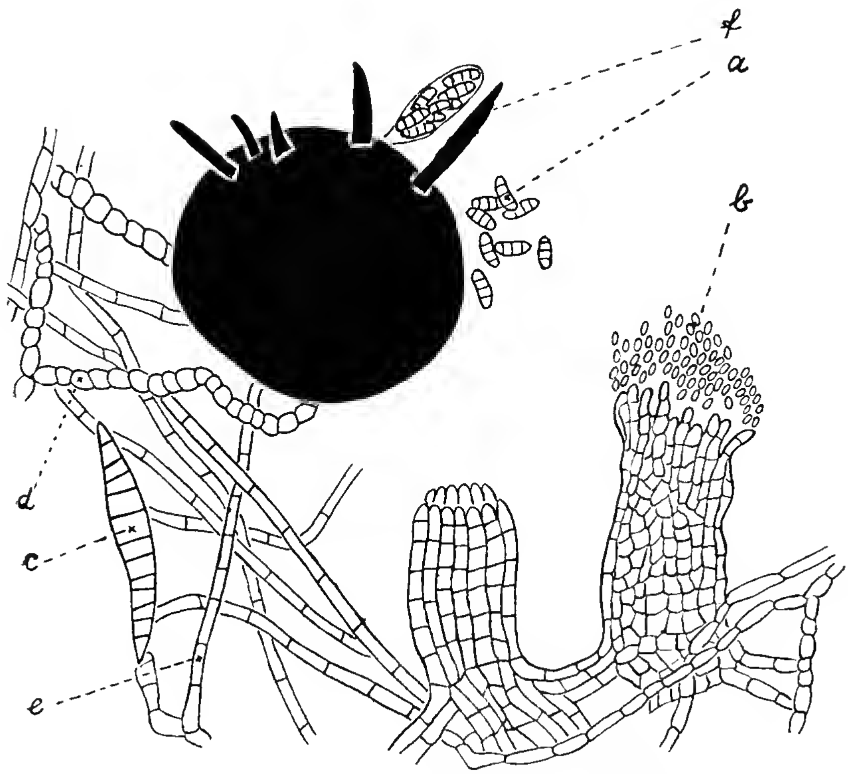

FIG. 1.—*Setella halophila* n.sp. from leaf of *Aegiceras corniculatum*, treated with lacto-phenol. a, ascospore; b, pycnospore; c, conidium; d and e, hyphae; f, bristle-like appendage to ascocarp. Camera-lucida drawing ×375.

Cylindrical pycnidia, measuring approximately 87·5 μ in length and 30 μ in width, are also formed in large numbers. The pycnidia are lighter brown in colour, and the hyphal structure of the wall is more readily discernible than that of the ascocarps. There are no bristle-like appendages. Pycnospores emerge in large masses (Fig. 1, b) through the mouth of the pycnidium, which is slightly fimbriate. The pycnospores are colourless, elliptical, non-septate, and measure 5 μ x 2·5 μ.

In addition to the formation of ascocarps and pycnidia, there is a sparse development of conidia. These are brown, spindle-shaped, phragmoseptate spores, measuring 65 μ in length, and at the broadest part 10 μ in width (Fig. 1, c).

This fungus has been referred to as a new species, because it differs in certain important respects from the only previously described species of the genus, *Setella*.

In *S. disseminata,* which was described by Sydow (1916) on species of bamboo, in the Philippines, the ascospores are much larger, measuring 20-30 μ x 9-10 μ. Also the pycnidia are different; in *S. disseminata* they are described (Sydow 1916) as globular and externally resembling ascocarps, but without bristles. Furthermore, in Sydow's species, mycelial development is sparse, in contrast to the abundant development of hyphae found in the species here described.

Chaetothyrium Citri (Arn.) Fisher

A 'sooty mould' which is identical macroscopically with that produced by *S. halophila* has been collected on *Aegiceras corniculatum* growing near Redcliffe, on the coast, 24 miles north-east of Brisbane. On microscopical examination, however, *Chaetothyrium Citri* (Arn.) Fisher was found to be the fungus responsible for this mould.

C. Citri has been recorded (Fisher 1940) from both coastal and inland districts in Victoria, but this is the first record of the species in Queensland. This collection was made in October, 1948; then, ascocarps were abundant and pycnidia very sparsely developed.

Under Victorian conditions, a definite seasonal cycle in spore development was observed, with a maximum development of the ascigerous stage during summer months (Fisher 1940, p. 195).

It has not been possible to make detailed observations on the life-cycle of *C. Citri* in southern Queensland, but it would appear that, under warmer climatic conditions, the formation of ascocarps occurs earlier than in Victoria.

It should also be noted that the ascocarps are devoid of bristles, and the hyaline, 3-6 septate ascospores, which measure 17·5-22·5 μ x 3·7-5 μ, are more uniform in size than in Victorian specimens.

II. Microthyriaceae Sacc.

Asterina systema-solare Mass. var. **minor** E. Fisher

Mycelio stellata saepe colonias sparsas formante 1-4 mm. diam. Hyphis brunneis septatis 2·5-3·75 μ diam. Hyphopodiis integris, 3·75-5 μ x 5-7·5 μ, vel convolutis, 7·5-10 μ x 10-15 μ. Ascocarpis radiantibus, ostiolatis, clypeatis 75-200 μ diam. Ascis octosporis, clavatis, 60-65 μ x 12·5-15 μ. Ascosporis brunneis, ellipticis, ovoidis, uniseptatis, 12·5-15 μ x 5-6 μ. *Hab.*: In summis foliis *Banksiae roboris,* Sunnybank, prope Brisbane, Queensland, Australia, September 1947; et *B. roboris* var. *minoris,* Beerwah, Queensland, Australia, October 1947.

Leg. E. Fisher (Typus in Kew et in Herb. auct.)

Asterina systema-solare Mass. var. *minor* E. Fisher forms a thin sooty film, of asterinoid type of growth, which occurs quite commonly on *Banksia robur* Cav. and on a variety with smaller leaves, *B. robur* Cav. var. *minor* Maid. and Camf. Collections have been made at Beerwah, approximately 50 miles north-east of Brisbane, also at Sunnybank, 10 miles south of Brisbane.

Before describing this new variety in detail, it is desirable that the species *Asterina systema-solare* Mass. should be reviewed.

Massee (1901) described the species *A. systema-solare* on the leaves of *Banksia marginata* Cav. collected in Tasmania by Rodway (1897). Ryan (1939) referred

this species to *Prillieuxina,* a genus which may be distinguished from *Asterina* by the absence of hyphopodia.

Through the courtesy of the Director, Royal Botanic Gardens, Kew, England, I have examined type-material of *A. systema-solare,* and hyphopodia are clearly present. (Plate IV, fig. 1.) Therefore, this species should not be included in the genus *Prillieuxina.*

Hyphopodia are not mentioned in Massee's original description of *A. systema-solare,* likewise there is no reference to the radial construction of the ascocarps, which is so characteristic of the Microthyriaceae. Furthermore, my examination of type-material has shown that the dimensions of the ascospores are larger than is indicated in Massee's original description.

In view of these ambiguities, and the discrepancy in spore measurements, *A. systema-solare* Mass. is now re-described, from Rodway's type, No. 540.

The mycelium forms black patches 0·5-1·5 mm. diam. on the upper surface of leaves of *Banksia marginata* Cav. Hyphae brown, septate, 2·5 μ diam., hyphopodia present, 5-10 μ x 7·5-22·5 μ. Ascocarps radially constructed, ostiolate, circular, shield-shaped, 150-260 μ diam. (Plate IV, fig. 2.) Asci 8-spored, thick-walled, clavate-ovoid, 55-67·5 μ in length x 17·5-22·5 μ in width. Ascospores brown, elliptical-ovoid, uni-septate, 15-17·5 μ x 6-7·5 μ.

Narrow, branched, colourless hyphae are intermingled with the asci, forming part of the hymenial layer. (Plate IV, fig. 3.) If these sterile hyphae are interpreted as paraphyses, and if the classification of Stevens and Ryan (1939) is followed, *A. systema-solare* should be transferred to the genus *Parasterina* Theiss. and Syd. This genus was created (Sydow 1917, p. 246) for the purpose of separating paraphysate species from other members of the genus, *Asterina* Lév.

Apparently realizing the difficulty of identifying paraphyses accurately, Theissen (1918, p. 4) later distinguished between true paraphyses, the ends of which are free, and 'paraphysoides', in which the ends of the hyphae are united to form a membranous layer covering the hymenium. Also, Ryan (1939, p. 78) has used the term 'pseudoparaphysate' to describe a species, referred to an aparaphysate genus.

It would appear, therefore, that the presence of paraphyses is not a reliable generic feature, and I will refer the species *A. systema-solare* to the genus *Asterina.*

The specimens collected by me have been referred to a new variety of *Asterina systema-solare* as the ascospores are smaller than in the type-material; also, the asci are narrower and more distinctly club-shaped. The hymenial layer contains fewer sterile hyphae than in Rodway's original material, but the specimen illustrated in Plate IV, fig. 5, has been focused to show one such colourless hypha.

The mycelium is sometimes well developed, forming an asterinoid type of growth over the entire upper surface of the host leaf, but it may form discrete isolated colonies approximately 1-4 mm. diam., similar to those described from Rodway's type-material.

Hyphae brown, septate, 2·5-3·75 μ diam. Hyphopodia may be entire, measuring 3·75-5 μ x 5-7·5 μ, or convoluted and measuring 7·5-10 μ x 10-15 μ. Ascocarps are radially constructed, ostiolate, circular shield-shaped, measuring 75-200 μ diam. (Plate IV, fig. 4.) Asci 8-spored, clavate, 60-65 μ x 12·5-15 μ. Ascospores brown, elliptical-ovoid, uni-septate, 12·5-15 μ x 5-6 μ. *Habitat*: On the upper surface of leaves of *Banksia robur* Cav., Sunnybank, near Brisbane, Queensland, Australia, September 1947; and *B. robur* Cav. var. *minor* Maid. and Camf., Beerwah, Queensland, Australia, October 1947.

Synonymy

Stevens and Ryan (1939) have included *Seynesia Banksiae* Henn. and *Didymosphaeria Banksiae* Cke. in the synonymy of *P. systema-solare* (Mass.) Ryan. It would appear that *Seynesia Banksiae* is correctly placed. Hennings (1903) described this species from the leaves of *Banksia* collected in southern Queensland; and although he does not indicate the species of host plant, Bailey (1909, p. 765) has recorded *S. Banksiae* or *Banksia latifolia* R.Br., a species which is synonymous with *B. robur* Cav.

Didymosphaeria Banksiae, on the other hand, should not be included in the synonymy of *P. systema-solare.* Cooke's description (1890) of *D. Banksiae* on leaves of *Banksia* collected in Victoria was prior to Massee's description of *A. systema-solare* (1901); and the examination of type-material has shown that the two species are distinct.

Miss E. M. Wakefield, who has examined the type-material of *D. Banksiae* on my behalf, comments that this species is 'erumpent with never a trace of superficial mycelium'. *A. systema-solare,* on the other hand, is characterized by a superficial mycelium bearing hyphopodia (Plate IV, fig. 1).

Furthermore, through the courtesy of the Director, Royal Botanic Gardens, Kew, I have been able to examine a specimen of *D. Banksiae* which is considered by Miss Wakefield to be identical with the type. In this specimen, which was collected by C. T. White at Cooloongatta, Queensland, not only is superficial mycelium completely lacking, but there is no evidence of radial construction of the ascocarps.

Therefore *D. Banksiae* Cke. is quite distinct from *A. systema-solare* Mass., and it should not be referred to the family *Microthyriaceae.*

III. Perisporiaceae Fr.

Meliola polytricha K. and C. var. **queenslandica** E. Fisher

Mycelio nigras colonias separatos formante, circiter 1-2 mm. diam. Hyphis brunneis, septatis, 7·5 μ diam. Hyphopodiis capitatis 10-15 μ x 17·5-25 μ. Setis aciculiformis, mycelii 320-400 μ longis x 7·5-8·5 μ latis ad basin. Ascocarpis globosis 150-250 μ diam. Ascis 2-sporis, solum sporis immaturis hyalinis in ascis visis. Maturis ascosporis brunneis, 4-septatis, cylindricis, utrinque obtusis, 55-65 μ x 17·5-22·5 μ. Conidiis brunneis 3-4 septatis, 30-40 μ x 7·5 μ, solum in specimene Bailey visis. *Hab.*: In summis foliis *Callistemon viminalis,* Gold Creek, prope Brisbane, Queensland, Australia, September 1947; *Callistemon,* Brisbane, Bailey's collection No. 633.

Leg. E. Fisher. (Typus in Kew et in Herb. auct.)

This fungus was found on *Callistemon viminalis* (Sol.) Cheel growing near Gold Creek, approximately 13 miles north-west of Brisbane.

An earlier collection on *Callistemon* in the Brisbane area was made by F. M. Bailey, and this was identified by Cooke as *Meliola polytricha* K. and C. Through the courtesy of the Director, Royal Botanic Gardens, Kew, I have been able to examine specimen No. 633 from Bailey's collection, and in the matter of ascospore measurements it agrees closely with the specimens collected by me. However, both of these collections differ from the type-material with which I was able to compare them, in that the ascospores are significantly larger.

Meliola polytricha K. and C. was described by Cooke (1880) from leaves of *Osyris compressa* and *Cunonia capensis,* collected in Natal, South Africa.

Cooke did not state the ascospore measurements, but Doidge (1915) has re-described the species and the measurements given by her, 45-55 μ x 16-18 μ, agree with my examination of types Nos. 1256 and 1262 from Kalchbrenner's herbarium.

The ascospores from Australian specimens are consistently larger; in Bailey's specimen No. 633, ascospores measured 57·5-60 μ x 17·5-22·5 μ and those from the Gold Creek collection on *Callistemon viminalis* were 55-65 μ x 17·5-22·5 μ.

Meliola polytricha var. *abyssinca* was described by Hennings (1893). In this variety the range of ascospore measurements is almost wide enough to include the Australian representatives of *M. polytricha*. However, the spores seen in Bailey's collection, and in my own, do not approach the lower limits of spore-size attributed to Henning's specimens, and so a new variety is described on *Callistemon viminalis*.

Meliola polytricha K. and C. var. *queenslandica* E. Fisher

Mycelium forms black colonies approximately 1-2 mm. diam. on both upper and lower surfaces of leaves. Hyphae dark brown, septate, 7·5 μ diam. Hyphopodia capitate 10-15 μ x 17·5-25 μ. Mycelial setae, 320-400 μ in length x 7·5-8·5 μ wide at the base, and tapering to an acute tip. Ascocarps globose, 150-250 μ diam. Asci are 2-spored; the wall of the ascus breaks down early and only immature colourless spores have been found inside an ascus. Mature ascospores are brown, 4-septate, cylindrical, rounded at both ends, 55-65 μ x 17·5-22·5 μ. Conidia were not observed on specimens collected by me, but on Bailey's material conidia were found, light brown, 3-4 septate, 30-40 μ x 7·5 μ.

Habitat: On leaves of *Callistemon viminalis* (Sol.) Cheel collected at Gold Creek, near Brisbane, Queensland, Australia, September 1947; *Callistemon*, Brisbane, Bailey's collection No. 633.

Summary

One new species and two new varieties of 'sooty mould' fungi are described.

The new species, *S. halophila* constitutes the first record of the genus *Setella* in Australia; and the occurrence of *Chaetothyrium Citri* is recorded for the first time in Queensland. There is no previous record of any representative of the family Chaetothyriaceae being collected in Queensland; and it is interesting to note that *S. halophila* and *C. Citri* have both been found on the leaves of *Aegiceras corniculatum*, a mangrove species, which excretes large quantities of salt.

The two new varieties, *Asterina systema-solare* var. *minor*, and *Meliola polytricha* var. *queenslandica*, represent the families Microthyriaceae and Perisporiaceae respectively.

Acknowledgments

I wish to thank Miss E. M. Wakefield, Herbarium, Kew, England, for supplying me with specimens and notes from publications unobtainable in Australia; also Mr. J. H. Willis, National Herbarium, Botanic Gardens, Melbourne, for the Latin diagnoses. The identification of the host plants was made by the staff of the National Herbarium, Botanic Gardens, Brisbane, and the photographs were taken by Mr. C. Illidge, Botany School, University of Queensland.

Portions of the type-specimen of *Setella halophila* n.sp., and of the new varieties herein described, have been sent to the Herbarium, Royal Botanic Gardens, Kew, England.

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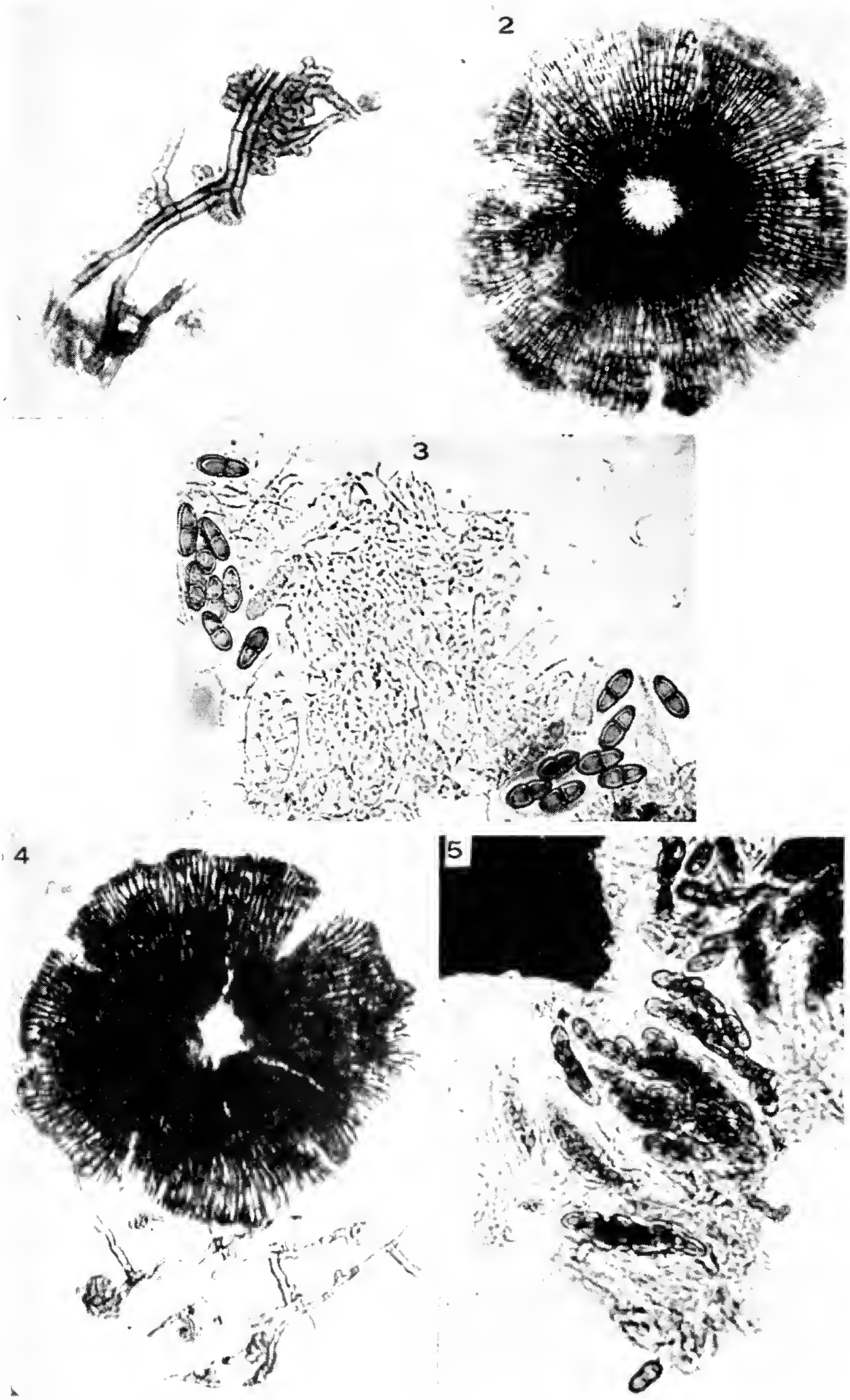
Explanation of Plate IV

Figs. 1-3. Rodway's type No. 540. *Asterina systema-solare* Mass.

Fig. 1.—Mycelium showing hyphopodia. ×350.
Fig. 2.—Ascocarp showing radial structure. ×208.
Fig. 3.—Contents of ascocarp showing sterile hyphae and asci containing ascospores. ×350.

Figs. 4 and 5. *Asterina systema-solare* Mass. var. *minor* E. Fisher.

Fig. 4.—Ascocarp showing radial structure and mycelium with hyphopodia. ×350.
Fig. 5.—Ascocarp ruptured to show contents. Note branched sterile hypha lying across ascus, in centre of photograph. ×350.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7

MIDDLE DEVONIAN CORALS FROM THE BUCHAN DISTRICT, VICTORIA

By Dorothy Hill, D.Sc.,
University of Queensland, Brisbane

[Read 10 November 1949]

Abstract

The fossil corals of the Buchan district, Victoria, are described and figured, including five new species of Rugosa and six of Tabulata, and the age of the Buchan Series deduced to be Couvinian. The occurrence of squamulae in the Favositidae is discussed, and the types found in the Buchan favositids described, with notes on the wall structure in *Favosites*.

Stratigraphic Palaeontology

The dominant Rugose coral families in the Buchan series are the *Acanthophyllidae* and *Disphyllidae*; and this shows that the series is Lower or Middle Devonian. Since the use without definition of these terms 'lower' and 'middle' results only in confusion, my definitions follow. My use of the Lower Devonian Stages is that of Asselberghs (1946), who has studied their priority of nomenclature. For the Middle Devonian Stages I follow Mailleux (see Lecompte, 1939, p. 6).

Epoch	Stage	*Sequence in the south of the Dinant Basin*
Middle Devonian	Givetian	Assise de Givet (*Stringocephalus* beds)
	Couvinian	Assise de Couvin (*Calceola* beds) Assise de Bure (*Spirifer cultrijugatus* beds)
Lower Devonian	Emsian, Dorlodot, 1900, p. 157	Grauwacke de Hierges (lower part) Schistes et grès de Winenne Grès et schistes de Vireux Grauwacke de Pesche
	Coblenzian, Dumont, 1848, p. 21 (= Siegenian of Dorlodot, 1900, p. 157, as used by Asselberghs, 1946)	Hundsruckian = Grauwackes de Petigny et St. Michel Taunusian = Grès d'Anor
	Gedinnian, Dumont, 1848, p. 4	Schistes de St. Hubert à Poudingue de Fépin

The Buchan series has been described by Teichert (1948, p. 60) as consisting of between two and three thousand feet of limestones and shales, and from his field mapping and collections three coral faunas may be recognized, which can be considered in relation to the standard sequence. These are, from below up, the Cave limestone fauna, the lower Murrindal fauna (associated with *Gyroceratites* and *Lobobactrites*), and the upper Murrindal fauna.

The CAVE LIMESTONE coral fauna includes *Acanthophyllum aequiseptatum* Hill, *A.* sp., *'Campophyllum' recessum* Hill (very abundant), *Disphyllum speleanum* sp. nov., *Pseudamplexus ?princeps* Eth., *Favosites bryani* Jones, *Thamnopora alterivalis* (Chapman), *Aulopora* cf. *conglomerata* Goldfuss, *Syringopora flaccida* sp. nov., and *Roemeria* sp. The Acanthophyllids are most like those from the limestones of Chaudefonds and Chalonnes, which are reasonably regarded as the Hercynian (Bohemian) facies of the Assise de Bure. The Disphyllid has no close overseas resemblances, while the *Pseudamplexus* is like that from the Emsian Hercynian limestone of Erbray. *F. bryani* has squamulae of a type seen in the Onondagan of North America and the Couvinian of Europe. *T. alterivalis* may be a member of the European *T. reticulata* group, and from the progressive changes in this group outlined by Lecompte it would seem to be older than upper Couvinian. *A. conglomerata* Goldfuss is Middle Devonian in Europe. The remaining Tabulata are not specially indicative of horizon. Direct comparison with European faunas indicates a horizon somewhere near the junction between Emsian and Couvinian, probably Couvinian. The whole fauna is closely related to the Murrumbidgee fauna of N.S.W., previously deduced to be Couvinian (Hill 1940c).

The coral fauna of the LOWER MURRINDAL beds includes *Lyrielasma* aff. *floriforme* Hill, *Disphyllum angulare* sp. nov., *Metriophyllum erisma* sp. nov., *Syringaxon radiatum* sp. nov., *Spongophyllum murale* sp. nov., *Favosites ? pluteus* sp. nov., *Gephuropora duni* Etheridge, *Thamnopora alterivalis, T. ? angulata* sp. nov., *T. tumulosa* sp. nov., and *Aulopora* cf. *conglomerata*. The fauna is largely of argillaceous-calcareous facies. *L. floriforme* occurs in the Tamworth district of N.S.W. in a limestone either Lower Devonian or Couvinian. In Europe *Metriophyllum* is not known before the Assise de Couvin. Neither the Disphyllid nor the Syringaxonid are specially indicative of horizon within the Devonian. *Spongophyllum murale* resembles German Givetian species. *Favosites pluteus* has squamulae of a type found in the Onondagan of North America and the Middle Devonian of Europe. *Gephuropora* is known outside Australia only in the Couvinian of the Ardennes. In N.S.W. it occurs in the Murrumbidgee Series (Couvinian). *T. alterivalis* is similar to the European Middle and Upper Devonian *T. reticulata*; *T. angulata* is perhaps closest to the long-ranged European *Thamnopora polyforata* from the Upper Couvinian and Givetian of the Ardennes. The age indicated by this assemblage is thus probably Couvinian.

The UPPER MURRINDAL coral fauna includes *Acanthophyllum* cf. *clermontense* Hill, *Xystriphyllum mitchelli* (Etheridge), *Disphyllum angulare, Metriophyllum* (?) *erisma, Alveolites stamineus* sp. nov., *Alveolites* sp., *'Coenites' expansus* de Koninck, *Favosites nitidus* Chapman, *F. bryani, F. stelliformis* (Chapman), *F. pluteus, Gephuropora duni, Thamnopora angulata* and *Roemeria ocellata* sp. nov. *A. clermontense* resembles the Eifel upper Couvinian Acanthophyllids in internal structure; *Xystriphyllum mitchelli* is not unlike *X. manipulatum* (Pocta) from the Upper Coblenzian or Lower Emsian Koneprus limestone of Bohemia. *Alveolites*

stamineus shows wall thickening characteristic of Devonian forms. *'Coenites' expansus* has resemblances to the European upper Couvinian and lower Givetian *'Coenites' escharoides*. *F. nitidus* has close similarity of internal structure to *F. alpina* Hörnes in Penecke from the Emsian of Graz. *F. bryani, F. stelliformis* and *F. pluteus* all have squamulae of types characteristic of the Onondagan of North America and the Couvinian of Europe; *Gephuropora duni* suggests the Couvinian; *Thamnopora angulata* is possibly related to the Middle Devonian European *T. polyforata* group, and *Roemeria ocellata* is similar to but larger than the Middle Devonian European genotype. Several of these species are characteristic of the Murrumbidgee series of N.S.W., considered to be Couvinian, e.g., *X. mitchelli, 'C.' expansus, F. nitidus, F. bryani, F. pluteus* and *G. duni*, while *F. stelliformis* is known elsewhere only from the Loomberah limestone (possibly Couvinian) of the Tamworth district of N.S.W. It seems likely then, that the upper Murrindal beds are Couvinian, probably upper Couvinian.

The age indicated for the Buchan beds by the corals it contains is therefore Couvinian. The Buchan beds would appear to be roughly equivalent to the Murrumbidgee beds of N.S.W., while the Clermont limestone of Queensland is possibly equivalent to the upper Murrindal beds.

ZOANTHARIA RUGOSA

Family Acanthophyllidae Hill, 1939a, p. 56; 1940, p. 250

Genus **Acanthophyllum** Dybowski; Hill, *idem.*

Acanthophyllum aequiseptatum Hill, 1940, p. 251

(Pl. V, fig. 1)

G.S.V.[1] 47765 from the Cave limestone of Loc. 97* is very like the Couvinian type of this species from the Bluff limestone of the Murrumbidgee series; its tabularium is however slightly wider, one third instead of one quarter the diameter of the corallite, and has some of its axial septal ends slightly curved.

Acanthophyllum sp.

(Pl. V, fig. 2)

G.S.V. 47713-4 from the *Spirifer* (= Cave) limestone of Loc. 82 differ from the Couvinian *A. aequiseptatum* in having the axial ends of their major septa long, somewhat dilated, tightly packed and twisted vortically.

Acanthophyllum aff. **clermontense** (Etheridge); Hill, 1939a, p. 57

(Pl. V, figs. 3a, b)

G.S.V. 48508 (Loc. 225) from the upper reef limestone in the upper Murrindal beds, and 48448 (Loc. 190) from somewhere in the middle of the Murrindal beds differ from the Couvinian types of this species from Clermont, Queensland, in having their septa more regularly thickened in the dissepimentarium, and their tabularium dominated by a few of the axial ends of the major septa which are longer and thicker than the others. It is probable that this characteristic is of specific value but my material is too scanty for certainty. This type of axial septal arrangement is seen in German species such as *'Rhopalophyllum' fibratum* Wdkd. from the upper Couvinian.

1. Geological Survey of Victoria collection.
* For details of localities see p. 160.

Genus **Lyrielasma** Hill, 1939b, p. 243

Lyrielasma aff. **floriforme** Hill

(Pl. V, figs. 4a, b)

Lyrielasma floriforme Hill, 1942c, p. 146. Holotype, Syd. Univ. 7252, from the lower Devonian or possibly Couvinian limestone in middle of south boundary Portion 277, Parish Burdekin, Tamworth district, N.S.W.

G.S.V. 48129 (Loc. 167) and 48460 (Loc. 233) from the Murrindal beds have a compound, fasciculate corallum, a ring of new corallites arising by peripheral increase from the dissepimentarium of a mature corallite; the new corallites are of small diameter at first (3 mm. or less) but rapidly widen to at least 14 mm. Where the corallites are crowded in the ring above their origin they become partly prismatic through mutual pressure. There are 18 major and 18 minor septa at a diameter of 6 mm., 22 of each at 12 mm., and 28 at 14 mm. They are dilated and in contact at the periphery to form a stereozone which may be up to 1 mm. in width, but is usually less, and is sometimes insignificant. The major septa are unequal but many attain the axis, and in the tabularium they are carinate. The minor septa are about two-thirds as long as the major. The dissepiments are steeply inclined, even the outermost series, and rather large. The tabularium is about 4·5 mm. wide in a corallite of 12 mm. diameter, and the tabular floors are funnel-shaped with a deep axial notch.

The Tamworth holotype has a narrow, nearly regular peripheral stereozone. In these two Victorian specimens the stereozone is less well marked, and the outer series of dissepiments are more steeply inclined. Since only the holotype is known from Tamworth, and only two specimens from Buchan, the limits of variation are unknown, and the Buchan specimens are provisionally described as *L.* aff. *floriforme.*

Genus **Xystriphyllum** Hill, 1939a, p. 62; 1940c, p. 269

Xystriphyllum mitchelli (Etheridge); Hill, 1940c, p. 269; 1942c, p. 147

(Pl. V, figs. 5, 6)

The species occurs in several localities in the upper Murrindal beds (upper reef limestone), Buchan district, Victoria, e.g., Rocky Camp; north side of hill, north of Rocky Camp; and new road cutting from Buchan township to the Spring Creek Caves, north boundary of allotments 10 and 18, Parish of Buchan.

Family Caniniidae

Genus **'Campophyllum'** auctt. Hill, 1940c, p. 254

'Campophyllum' recessum Hill, 1940c, p. 254

(Plate V, figs. 7, 8)

Campophyllum gregorii Chapman, 1912, p. 219, pl. XXXIV; non Etheridge, 1892.

This species, whose type locality is Devil's Elbow in the Couvinian Murrumbidgee beds, is prolific almost to the exclusion of others, in the Cave limestone in Spring Creek, Caves Reserve, Buchan. Fragmentary material from the Cave limestone of Loc. 97 and the equivalent *Spirifer* limestone of Locs. 13 and 36 is doubtfully referred to this species. In addition, fragmentary material (G.S.V. 48207B and 48212) from the Murrindal beds of Loc. 177 which I have for the present doubtfully included in *Disphyllum angulare* may be related to *'C.' recessum.*

Family DISPHYLLIDAE; Hill, 1939b, p. 224

Genus **Disphyllum** de Fromentel

Disphyllum de Fromentel; Lang and Smith, 1935, p. 544; Hill, 1940b, p. 398; Hill, 1942a, p. 247; Hill, 1942d, p. 185.

Disphyllum speleanum sp. nov.

(Pl. VI, figs. 9a, b)

Holotype. G.S.V. 47763B, from the Cave limestone, Loc. 96 Couvinian. No other specimen known.

Diagnosis. Slender, phaceloid *Disphyllum* with long septa dilated in the tabularium; with up to six series of small, highly globose dissepiments, and flat tabulae.

Description. The corallites are 5 or 6 mm. in diameter and epithecate; increase is axial, several new corallites arising simultaneously. There are 15 to 19 septa of each order, the major septa reaching unequally almost to the axis. The minor septa extend about half way to the axis. Both orders are dilated in the dissepimentarium and frequently close the interseptal loculi; as seen in vertical section they consist of trabeculae arranged in two zones; in a narrow outer zone these are directed upwards and inwards, in a wide inner zone (still in the dissepimentarium) they are arranged like a fan, directed dominantly upwards but falling outwards on the outer side and inwards on the inner side. In the tabularium the major septa are less and irregularly dilated and are somewhat wavy. The dissepiments are very small and globose or elongated in the vertical plane and arranged somewhat irregularly in three to six series. The tabulae are horizontal, thin and close.

Remarks. The species differs from *D. mesa* Hill (1942d, p. 185) from the late lower Devonian Garra beds of N.S.W. in having flat, not mesa-shaped tabulae, and in having smaller dissepiments developed in more series. There are no close resemblances to overseas species.

Disphyllum angulare sp. nov.

(Pl. VI, figs. 10a-c)

Holotype. G.S.V. 48079, lower Murrindal beds, Loc. 156, Couvinian.

Diagnosis. Solitary or compound *Disphyllum* with minor septa withdrawn in adult stages, leaving dissepiments arranged in an angular irregular herringbone pattern as seen in transverse section.

Description. The corallum is solitary or the corallites are aggregated in a manner suggesting a phaceloid or cerioid corallum, though the type of increase is unknown. The individual corallites are trochoid or cylindrical with a trochoid early stage, and may attain a diameter of 20 mm. Their epitheca shows transverse growth striation, and narrow vertical grooves at the position of major and minor septa, separated in the distal parts of the corallite by broad flat regions which may have a narrow median vertical channel.

There are 23 septa of each order at a diameter of 10 mm., increasing to about 30 at 20 mm. The major septa are long and are directed towards an excentric axis, but stop short of this, leaving an empty space 2 to 3 mm. wide; their axial ends may be slightly curved as they approach this space. The minor septa are short, and project but little inside a peripheral stereozone 1 to 1·5 mm. wide, formed by

the septa of both orders becoming dilated and by the deposition of tissue on the upper surfaces of the dissepiments between them. The tabularium is very wide, and the sagging tabulae are reinforced at its margin by numerous small plates closely resembling dissepiments, which meet at an angle in the loculi between the major septa; or are themselves angulate, the elbow being directed outwards in transverse section. There are one or two vertical series of dissepiments in the peripheral stereozone, and the dissepiments are globose and thickened by the upward growth of their constituent fibres.

Localities. This species has been collected from three localities in the Murrindal beds. In addition to the type locality it is known from the lower Murrindal beds of Loc. 145 and the upper Murrindal beds of Loc. 177.

Family METRIOPHYLLIDAE Hill, 1939c, p. 143

Genus **Metriophyllum** Edwards and Haime; Hill, 1939c, p. 144

Metriophyllum erisma sp. nov.

(Pl. VI, figs. 11, 12)

Holotype. G.S.V. 48901 (specimen reduced to a thin vertical section), Loc. 167, lower Murrindal beds, Couvinian.

Diagnosis. Metriophyllum with septal flanges inclined inwards and downwards, and with the inner tabulae sweeping vertically downwards about the axial structure.

Description. The corallum is almost cylindrical in its distal part, increasing in diameter from 4 mm. to 6 mm. in 8 mm. The major septa are 18 in number at a diameter of 5 mm. They meet at the axis of the corallum, forming a dense axial structure 2 to 3 mm. wide. Their sides are flanged, by slender, straight, plate-like outgrowths of septal tissue, which are directed downwards and inwards from the periphery, at a moderate angle as seen in median vertical section; in transverse section these appear as thickenings of the septa, or as slender plates like extra septa, running parallel to the septa. The thickness of the septa is variable from one section to another. Minor septa are not developed or are buried in the peripheral stereozone. The tabulae bound the axial structure by descending almost vertically around it; occasional outer tabulae proceed from the structure downwards and outwards to the periphery. There are no dissepiments.

Occurrence. The species characterizes the nodular Murrindal beds, specimens having been collected from Localities 3 and 55, in addition to the type locality.

Remarks. I am unconvinced by the evidence accepted by Smith (1945, pl. 34, fig. 3) for the identity of *Lopholasma carinatum* Simpson and *Stereolasma rectum* Hall, and regard only *L. carinatum* as congeneric with *Metriophyllum.*

Family MYCOPHYLLIDAE Hill, 1940a, p. 156

Genus **Pseudamplexus** Weissermel; Hill, 1940a, p. 157

Pseudamplexus ?princeps (Etheridge); Hill and Jones, 1940, p. 185

Only one specimen is known from the Buchan district—Melb. Univ. specimen C.Q.6 from Caves road quarry; its peripheral stereozone and the number of septa are as in the Lower Devonian types of the species, but as it is not certain that the Victorian form can be sub-compound like typical *princeps* it is included only doubtfully.

Family Spongophyllidae Hill, 1939a, p. 58; 1942a, p. 254

Genus **Spongophyllum** Edwards and Haime; Hill, 1939a, p. 60

Spongophyllum murale sp. nov.

(Pl. VI, figs. 13a, b)

Holotype. F.10272 Univ. of Q'ld. coll.; locality uncertain, probably Martin Cameron's quarry, Buchan. Dr. Teichert regards this quarry as in a bioherm in the lower Murrindal beds. Couvinian.

Diagnosis. Phaceloid *Spongophyllum* with very slender corallites with a wide peripheral stereozone.

Description. The corallum is fasciculate; the individuals, from 2 to 3 mm. in diameter, are somewhat crowded but parallelism of growth is not absolute. There are 12 long, unequal, wavy major septa extending almost to the axis; at the periphery they suddenly dilate to form with the similarly dilated alternating minor septa a stereozone about 0·25 mm. wide, from which however the minor septa do not project. Spines project from the sides of the septa, whose trabeculae are directed upwards and inwards from the wall. Large dissepiments are developed in a single series; though not infallibly, they are globose and lonsdaleoid, the septa frequently being discontinuous across them. The tabulae are thin, sagging plates.

Remarks. The spines on the sides of the wavy septa, the sagging tabulae, the lonsdaleoid dissepiments and the thick peripheral stereozone are all characteristic of the German *S. parvistella* Schlüter, which is however cerioid and is characteristic of the Givetian. There are resemblances also to *Fascicularia conglomeratum* Schlüter, also Givetian, but the lonsdaleoid dissepiments in our species indicate its relationship to *Spongophyllum*.

Family Syringaxonidae Hill, 1939c, p. 141

Genus **Syringaxon** Lindström, 1882, p. 20; Butler, 1935, p. 117

Genotype (by monotypy), *Cyathaxonia siluriensis* McCoy, 1850, p. 281; Upper Ludlow, Underbarrow, Kendal, Westmorland.

Diagnosis. Small, solitary, conical or cylindrical Rugose corals with an aulos formed by the dilatation of the axial ends of the septa which are withdrawn from the axis, and reinforced by tabular thickening; and a peripheral stereozone formed by dilation of the peripheral ends of the septa; with contratingent minor septa, and without dissepiments; with aular tabulae horizontal and outer tabulae declined from the aulos.

Range. Woolhope Limestone (base of Wenlock) to upper Middle Devonian; possibly, however, undescribed specimens in the Sedgwick Museum from the Caradocian Robeston Wathen and Coniston limestones belong to the genus; and Prantl accepts in it a Russian Upper Devonian or Devono-Carboniferous species.

Remarks. The American Niagaran genus *Laccophyllum* Simpson, 1900, and the Bohemian Silurian and Devonian *Alleynia* Pocta, 1902, are usually regarded as identical with *Syringaxon*; the latter certainly shows the characteristic septal dilatation, but the type species of the former (Smith, 1945, pl. 1, fig. 18) is as little dilated as is the genotype of *Barrandeophyllum,* a genus usually regarded as distinct by reason of this less septal dilatation, an irregular aulos, and the development of supplementary tabulae. Although these are differences of degree, they may well have generic significance and the family requires study.

Prantl (1938, p. 25) remarks that the amount of thickening in different specimens of a Middle Devonian Bohemian species of *Syringaxon* is greatest in specimens from shales, and least in specimens from limestone.

Syringaxon radiatum sp. nov.

(Pl. VI, figs. 14, 15)

Holotype. G.S.V. 48113 (thin section only), Loc. 167, lower Murrindal beds, Couvinian.

Diagnosis. Syringaxon with a wide peripheral stereozone but little septal dilatation at the narrow aulos, and with numerous septa, the minor being long.

Description. The corallum is conical, increasing in diameter from 5 to 10 mm. in 15 mm. There are 24 major and 24 minor septa at a diameter of 10 mm.; they are all dilated and in contact at the periphery to form an irregular stereozone about 1 mm. wide. The major septa are radial rather than pinnate in arrangement; they are relatively thin between this zone and the zone where the contratingent minor septa abut on them, and thereafter swell slightly but gradually to the aulos, where however the dilatation is less than in most species of the genus; they project slightly inside the aulos, decreasing rapidly to a sharp edge, usually without turning towards one another there. The minor septa are about half as long as the major septa, on which they are contratingent, the pair on either side of the counter septum being a little longer than the others and abutting on the counter septum. Occasional discrete vertical trabeculae are observed at the axis. The trabeculae in the septa are very close together, and are directed upwards and outwards. The dilatation of the septa at the aulos is not always sufficient to form an aulos unaided, and the tube is then completed by thickening of the aular tabulae. The tabulae within the aulos are horizontal or with slightly upturned edges, and are variably distanced—from 0·2 to 1·6 mm. apart; the outer tabulae are steeply declined from aulos to periphery, some being complete, but there are supplementary plates either at the aulos or at the periphery. Occasionally in the distal parts of the corallite a few dissepiments may be developed between one minor septum and its neighbouring major septum, but a continuous dissepimentarium is never formed.

Remarks. Only two specimens are known, both from the same locality. One has been used to give a thin transverse section, and the other to give a vertical section. The species shows much less dilatation than the Silurian genotypes; it retains the peripheral stereozone of the genus, but the dilatation at the aulos is almost as small as in the Middle Devonian *Barrandeophyllum* and the American Niagaran *Laccophyllum*. None of its features can as yet be recognized as characteristic of the species of any one age.

ZOANTHARIA TABULATA

Family ALVEOLITIDAE Duncan; Lecompte, 1939, p. 17

Genus **Alveolites** Lamarck, 1801; Hill, 1936, p. 33. Lecompte, 1939, p. 17

Alveolites stamineus sp. nov.

(Pl. VI, figs. 16a, b)

Holotype. Melb. Univ. Coll. 1954, slides 645 and 646. Couvinian, Murrindal, near Buchan, Vic.

Diagnosis. Discoid or laminar *Alveolites* with alveolitoid or semilunar corallites twice as wide as high (0·7 mm. and 0·35 mm.), with walls up to 0·2 mm. thick,

with mural pores 0·2 mm. wide and distant 0·65 mm. from centre to centre on the side walls of corallites; with numerous small spines, especially in the upper walls, and with thin, somewhat irregular tabulae.

Description. The corallum is massive, discoidal or laminar. The number of neighbouring corallites which have a parallel growth is not great, giving the calical surface an appearance of swirling turbulence. The corallites open obliquely, the angle of dip being 50° to 60°. They have an arched upper wall, and the bases of the sides of the arch typically rest on the crests of the arches of two neighbouring lower corallites. The regularity of the arrangement may be overcome, and the corallites then tend to be rectangular in section. The arch is a low one, and is evenly thickened, not produced into an angular projection at the crest. The average width of the corallite between the bases of the arch is about 0·7 mm. (from median line to median line), and the average height 0·35 mm. There are patches in the corallum where the walls are thicker than elsewhere, the maximum observed in such a patch being 0·2 mm. In the thinner-walled patches the thickness of the common walls was 0·1 mm. Each common wall is seen to be made of fibres directed upwards and inwards to the lumen from the median line. Small blunt spines project into the lumen, more from the upper arched wall than from the lower wall. Mural pores are about 0·2 mm. in diameter and their centres are about 0·65 mm. apart. They are developed on the upper wall, but only along the bases of the arch. Tabulae are usually complete, sometimes slightly domed, or saucered or inclined, and unequally spaced.

Range. The species is known also from the upper reef limestone of the upper Murrindal beds of Loc. 225. The thickening of the walls is characteristic of the Devonian alveolitids.

Alveolites sp.

(Pl. VI, figs. 17, 18)

G.S.V. 48507 (Loc. 225) and 48492 (Loc. 230), both from the upper reef limestones in the Couvinian upper Murrindal beds, have much thicker walls than *A. stamineus*. The average dimensions of the corallites are 0·6 x 0·4 mm. (from median line to median line), and the thickness of the wall is 0·2 to 0·3 mm., against 0·1 to 0·2 mm. in *A. stamineus*. Septal spines have not been noted in the few sections available; mural pores are common, at the bases of the upper or arched walls. The tabulae are as in *A. stamineus*.

Genus **Coenites** auctt.; Lecompte, 1939, p. 62

Remarks. *Coenites* Eichwald has as genolectotype *C. juniperinus* Eichwald from the drift of Vilna, Russia. Nicholson (1879) regarded a species from the Wenlock limestone of Stoke Edith, England, as identical with *C. juniperinus*, and interpreted *Coenites* upon this English form. As no thin sections of the type specimens of *C. juniperinus* are available, one cannot be certain that *Coenites* of Nicholson and other authors is in fact *Coenites* Eichwald. Lecompte has discussed the relation between *Cladopora*, '*Limaria*' and *Coenites*.

Diagnosis. 'Corallum ramose, laminar or massive, but in this last case finely zoned. Corallites conical in very limited development, because of the rapid thickening of the walls, with progressive constriction of the lumen causing precocious senility. Calices semi-lunar or horse-shoe-shaped. Tabulae few. Mural pores rare.

Septa occasionally represented by three processes in the calices.' (Lecompte, 1939, p. 62).

'Coenites' expansus de Koninck

(Pl. VI, figs. 19a-c)

Coenites expansus de Koninck, 1876, p. 74, pl. 2, fig. 3, from a very dark, black limestone in the Murrumbidgee Valley, Yass district. Couvinian. [The specimen figured by de Koninck, in which the coral tissue was more resistant to weathering than the limestone, in all probability was derived from the nearly black sponge limestone, of Cavan, in which the coral tissue is replaced by silica and weathers out in relief.]

Non Coenites expansus Frech, 1886, which is *Coenites escharoides* Steininger, from the Upper Couvinian and Lower Givetian of the Ardennes and the Eifel (Lecompte. 1939, p. 65).

Neotype. Univ. Q'ld. F.4269 (D. Hill Coll.), from the Couvinian sponge limestone of Cavan, N.S.W. The specimen is in black limestone with the coral tissue silicified and standing out in relief.

Diagnosis. Foliaceous Tabulate corals with some reticulation of the foliae, which are 3 or 4 mm. thick; with corallites diverging from a not always median plane to open obliquely on both surfaces of the folia; the walls of the corallites are thickened throughout, but the thickening increases distally. Mural pores and tabulae few.

Description. The corallum is foliaceous, the foliae being undulating and 3 or 4 mm. thick; the growing edge of one folia sometimes abuts the surface of another, so that the corallum is reticulate in a few places. The corallites diverge from a plane within the folia, not necessarily always median, each proceeding upwards nearly in this plane, towards the growing edge of the lamina for some short distance, and then turning suddenly outwards and proceeding to the surface at an angle of about 45°. Each corallite is alveolitoid, i.e., it is reclined, its outer or upper surface forming a low arch, while its lower surface imitates the shape of the corallites below it; the corallites of one layer alternate with those of another. The narrow lumen remains constant in diameter throughout, being little more than 1 mm. from the lower to the upper margin, but the distance from side to side may be twice this or more. The wall increases in thickness gradually from origin to calice. The fibres of the wall are arranged roughly at right angles to the margin of the lumen, and the thickness of the common wall between two lumina is equal to or greater than the height of the lumen. Septal spines have not been distinguished in sections, and no undamaged calices are available for study. The mural pores are just over 0·1 mm. in diameter, and are moderately abundant. Tabulae are rarely seen.

Remarks. The species is represented at Buchan, Victoria, in the Couvinian upper Murindal beds of Loc. 177. It resembles the upper Couvinian and lower Givetian *'Coenites' escharoides* in the form of the corallum, but differs in having less contrast between the dilatation of corallite walls in the axial and outer regions. In growth form also it is similar to *Thamnopora foliata* Jones from the Couvinian of Clermont, but this latter species has polygonal rather than alveolitoid corallites. A closely related form occurs in the Couvinian at Weejasper, N.S.W., differing only in having thinner, rather more regular foliae, and in having rather less dilatation in the axial plane of the foliae.

Family FAVOSITIDAE; Lecompte, 1939, p. 80

Genus **Favosites** Lamarck, 1816. Lecompte, 1939, p. 80

Wall Structure in Favosites. Swann (1947, p. 246), in an able discussion of North American Devonian favositids, has considered that a coenozone consisting of calcareous tissue laid down by a coenosarc may appear in some. In such cases he describes the common wall between two corallites as consisting of: (1) peripheral stereozone of corallite A (consisting of fibrous calcite arranged at right angles to the growth lamellae); (2) 'primordial wall' of corallite A (thin, opaque and structureless); (3) coenozone of homogeneous dense appearing calcite, cryptocrystalline, 'not evidently fibrous', with a very strong preferred orientation with the 'c' axis of the crystal vertical. The cryptocrystalline form is in some instances replaced by larger needle-shaped or prismatic crystals that have the same crystallographic orientation; (4) 'primordial wall' of corallite B; (5) peripheral stereozone of corallite B. Had Swann's figures shown this 'coenozone' actually to consist of fibrous calcium carbonate, like the peripheral stereozone and all coral tissue with the exception of the epitheca (Bryan and Hill 1941, p. 80), it would be necessary to accept the idea of the occurrence of a coenosarc in Favositidae. But they do not, and neither does any of the favositid material which I have studied as yet. I suggest that this 'coenozone' in Favositidae may be a fossilization phenomenon, caused by recrystallization along the plane of junction of two sets of fibres, each differently oriented; the crystallization perhaps assisted by the presence of $CaCO_3$ rich water finding easy access along such planes. A similar phenomenon is seen along the median line of the septa in some of the specimens of the rugose coral genus *Pycnactis* from the Silurian of Britain. On general grounds also I find it difficult to accept the occurrence of a coenosarc in Favositidae. Had it occurred, one would expect evolution to have made play with it, and produced species and genera characterized by different developments of it; but such are not found.

Squamulae. These are horizontal or slightly inclined flat or curved plates projecting with a free inner edge into the lumen of favositid corals; they may be linguiform, or broad and flat and of even thickness, or eaves-like, thickening in a vertical plane towards the base. They were formed of fibrous calcium carbonate (in some cases more than one trabecula is distinguishable), the fibres seemingly being continuous with those of the peripheral stereozone of the wall. Sometimes they bear a very close relation to the mural pores, being developed from the fibrous tissue of their upper and lower rims (e.g., the eaves-like types in the Australian corals described herein, and in *Emmonsia*). At other times they bear no obvious relation to the mural pores, as in the linguiform type developed in the *F. alpenensis* lineage from the Middle Devonian Traverse group of Michigan, so ably described by Swann (1947). Their fibres diverge from their points of origin in the median line of the common wall, and they are thus septal in origin; they were apparently laid down in invaginations in the sides of the base of the polyp.

Squamulae first appeared in the Upper Silurian (Ludlovian) of Asia Minor (Weissermel 1939, pl. 6, figs. 1, 2) in *Emmonsia* sp.; in the Lower Devonian of Bohemia (Pocta 1902, pl. 102, figs. 2, 3) they may be present in *F. intricatus* Barrande; and they are present in the early Couvinian (Co_1) limestone of Chaudefords and Chalonnes, France, in *F. ottiliae* Penecke, Le Maitre (1934, pl. VII, figs. 9, 10) and *F. alpina* Hörnes, Le Maitre (1934, pl. VIII, figs. 7-9), and in the upper Couvinian (Co_2) limestone of Dinant, Belgium, in *F. chaetetoides* (Lecompte, 1939, pl. XVIII, fig. 15). They are common in favositids and in

Emmonsia of the Onondagan (Couvinian) of North America, while in the Givetian of Europe they characterize *Caliapora*. They are known also in the Lower Carboniferous of Europe in *Emmonsia parasitica* (Smith and Gullick 1925, pl. VIII). They also occur in *Alveolites*, e.g. *A. fornicatus*, of the Couvinian of north-west Europe and Morocco.

Squamulae in Australian Favosites. Eaves-like squamulae occur in the following Couvinian *Favosites* in Australia: *F. nitidus, F. stelliformis, F. murrumbidgeensis* and *F. bryani*. Typically thin septal spines occur in addition to the squamulae, sometimes being very common. Eaves-type squamulae are developed in pairs, back to back, one in the lumen on each side of the mural pore. Each is formed by the projection of the fibrous tissue of the rim, almost invariably the upper rim of the mural pore. Thus near the median line of the wall they are lightly domed, but this curvature decreases towards the free inner end. They thicken upwards and downwards towards their base at the wall. Their fibres radiate from the median line of the wall, and the outer fibres are shorter than the inner, so that the shape in vertical section is that of a rose thorn, usually directed a little upwards. They are broad in transverse section, where they appear as the projection nearly to the axis of the lumen of the fibres of the greater (median) part of the peripheral stereozone. Their fibres may diverge outwards in this section also. In rare cases they may be seen to be composed of two or more trabeculae. These four species possess in common the arrangement of the mural pores in single series in the middle of the walls; the pores are circular in *F. nitidus, murrumbidgeensis* and *bryani,* but oval in *F. stelliformis.* Indeed the specific differences between the first three named species are differences only in degree, and they seem to form a related group.

A somewhat different type of squamula, the shelf-type, is seen in *F. pluteus* from the Murrindal beds of Buchan. Here the squamulae do not thicken upwards and downwards towards the base, nor thin towards their inner, free edge, as in the eaves-type, but retain the same thickness throughout. They are less obviously associated with mural pores, and only occasionally show any curving about a pore. They are also wider than the eaves-type. It seems possible, however, that *F. pluteus* may have developed from *F. bryani.*

Favosites nitidus Chapman; Hill and Jones, 1940, p. 198, pl. VI, figs. 3a-c
(Pl. VII, figs. 20a, b)

G.S.V. 48507A from the upper reef limestone of the upper Murrindal beds (Loc. 225), Buchan district, Couvinian, differs from the lectotype (from Cooper's Creek, behind the Copper Mine, Walhalla) in having its septal apparatus almost entirely of very thin, long, close septal spines, horizontal or only slightly inclined upwards. Eaves-like squamulae, which are fairly common in addition to septal spines in the type specimen, are rather infrequent in this Buchan specimen, but as in the type specimen are formed by the greater lateral growth of the fibres from spine centres above the mural pores, so that the spines coalesce into squamulae. Its dimensions are those of the type—the diameter of the polygonal corallites with somewhat rounded angles is 0·5 mm.; the thickness of the common wall is 0·12 mm.; the diameter of the uniserial mural pores is 0·15 mm., their centres being 0·3 to 0·4 mm. apart. Occasionally the pores are biserial and alternating, but this is less common than in the type; sometimes the pores are somewhat oval in the type specimen, but usually they are circular and only circular ones are observed in the Buchan specimen. In the spacing of the tabulae, which are slightly sagging, it is close to the type, 15 as against 13 in 5 mm. The Buchan specimen is a weathered

cylindrical fragment; new corallites arise in it by the growth of a partition across a portion of the lumen of an old corallite, frequently including two angles, in a type of peripheral increase. Its external structure has close similarity to *F. alpina* Hörnes in Penecke (1894, pl. IX, figs. 13, 14) from the Emsian *barrandei* beds of Graz.

I have two specimens from the Bluff Limestone of Clear Hill, Cavan, Murrumbidgee River, N.S.W., in which squamulae are more numerous than discrete spines. The Clermont (Q.) specimen figured by Jones (1941, pl. 1, fig. 2) also resembles the lectotype more closely than does the Buchan specimen. Univ. Q'ld. F.316 from Toongabbie, Victoria, resembles the Buchan specimen very closely in the important development of discrete septal spines.

Etheridge's (1899, pl. XXVII, figs. 1, 2) *F. basaltica* var. *salebrosa* from the Woolomol limestone of Tamworth, N.S.W., has, like *nitidus*, corallites of 0·5 mm. in diameter, and mural pores in a single vertical series on each corallite face, but in its holotype the corallites are frequently alveolitoid, the pores are about 0·75 mm. apart, and squamulae have not been observed.

F. nitidus bears sufficient resemblance to *F. stelliformis* as to suggest relation between the two.

Favosites stelliformis (Chapman)

(Pl. VII, figs. 21, 22)

Chaetetes stelliformis Chapman, 1918, p. 393, pl. XLII, figs. 1-3.

Whereabouts of type specimen and figured thin sections unknown. One thin vertical section, marked 'Dupl.' in Chapman's writing, is in W. N. Benson's Collection. Loomberah Limestone, possibly Couvinian, Tamworth district.

Diagnosis. Favosites with polygonal corallites 0·5 mm. in diameter with a single median series of large oval pores on each face, each pore of a series separated from its neighbour by a narrow horizontal eaves-like squamula; with the tabulae tending to be developed at the same levels throughout the corallum.

Description. The corallum is massive, probably hemispherical, with the corallites absolutely straight in course, and about 0·5 mm. in diameter. They are polygonal, the angles are not rounded, and the walls are about 0·05 mm. thick; gaps are frequently present in the walls in transverse section owing to the frequency of the mural pores, which are very numerous, regularly developed, and oval, being 0·25 mm. high and 0·19 mm. wide (or narrower); they are closely and fairly regularly spaced in the series, there being 0·125 to 0·25 mm. between the top of one pore and the bottom of the next. The septal apparatus is represented by two or more trabeculae projecting from the middle of the wall between each of the pores of a series, coalescing so as to form an eaves-like squamula with a broad and tall base and a long but narrow wedge-like projection, tapering rapidly in the vertical plane but less rapidly in the horizontal plane. The squamulae from either side of a common wall between two corallites are opposite. Septal spines projecting singly from other parts of the wall are rare. The tabulae are slightly sagging, and distant, usually with either two or three mural pores contained between two neighbours, but they tend to be developed at the same levels throughout the corallum, giving it a regularly zoned appearance.

Remarks. The possession of mural pores and septal trabeculae causes this species to be removed from *Chaetetes.* Its unusual characters, the numerous oval pores separated by squamular aggregations of trabeculae, and the regular tabular floors throughout the corallum suggest it might be wise to erect a new genus for it.

But as only two specimens are known so far, one from the possibly Couvinian Loomberah limestones of N.S.W. (the exact limestone lens is not known) and the second, G.S.V. 48541, from the upper Murrindal beds at Rocky Camp, Buchan, the species is for the moment referred to *Favosites*. I have seen no foreign species with similar characters. The Buchan specimen contains several spiral tubes, each rising about or within the wall of a single corallite, which I take to be worm tubes.

Favosites bryani Jones

(Pl. VII, figs. 23, 24)

? *Favosites squamulifera* Etheridge, 1899, p. 166, pl. XXXVIII, figs. 4, 5. Tamworth, N.S.W. Devonian, horizon and exact locality unknown, considered by Etheridge to be Woolomol Limestone because of lithological character of specimens. Type specimen not located.

? *Favosites basaltica* var. *moonbiensis* Etheridge, 1899, p. 164, pl. XXIV, figs. 1, 2; pl. XXIX, fig. 2; Jones, 1937, pl. XV, figs. 1, 2. Beedle's Freehold, near Moonbi, north-east of Tamworth, Moonbi Limestone. Type specimen not located.

? *Favosites murrumbidgeensis* Jones MS. in Allan, 1935, p. 7, pl. IV, figs. 5, 6. Holotype from Clear Hill, Cavan, N.S.W. (Couvinian Bluff Limestone), figd. Jones, 1937, pl. XVI, figs. 3-4. Allan's figured specimen was from the Couvinian Reefton limestone, New Zealand.

Favosites bryani Jones, 1937, p. 96, pl. XV, figs. 3-6, Couvinian, Goodhope and Taemas Bridge, Yass district. Hill and Jones, 1940, p. 190, pl. V, figs. 2a, 2b, Coblenzian, Molong district, N.S.W.; Jones, 1941, p. 42, pl. I, fig. 1, Couvinian, Clermont, Queensland; and a doubtful record by Hill, 1942b, p. 8, pl. II, fig. 6, from Pt. Hibbs, Tasmania.

Holotype (by designation). A.M.F.5550, Goodhope, near Yass, N.S.W., figd. Jones 1937, pl. XV, figs. 3, 4.

Diagnosis. Favosites with thick-walled (0·125 mm.) polygonal corallites 1 mm. in diameter, with a single median row of round mural pores (0·25 in diameter, and 0·6 mm. between centres); with the fibres of the septal trabeculae at the upper and sometimes the lower rims of pores grouped in long sharp-edged eaves-like squamulae; discrete septal spines also occur at the sides of the mural pores. Tabulae numerous, up to 18 in 5 mm., usually complete and horizontal, sometimes inclined or sagging and suspended from squamulae.

Remarks. I have been unable to locate the type specimens of the first two forms mentioned in the synonymic list above as of doubtful identity with *F. bryani,* but wish to draw attention to the possibility that *bryani* might well be related to one of them. I have examined the holotype of *F. murrumbidgeensis* (A.M.F. 9576) and find that its characters are very close to those of *F. bryani,* differing only in a slightly smaller size of corallite (0·9 mm. as against 1 mm.), in smaller mural pores (0·15 as against 0·25 mm.), and in the much higher proportion of the tabulae which are suspended from the eaves-like squamulae. The true relation between these two will only be elucidated after an exhaustive study of our Australian lower Middle Devonian *Favosites.* Since only *murrumbidgeensis* has so far been recorded from New Zealand, the two species are regarded as distinct, though both occur in the Bluff limestone of Clear Hill, Cavan, N.S.W. Only *F. bryani* is so far found in Victorian Middle Devonian beds.

G.S.V. 47763, Cave limestone (Loc. 96), has smaller corallites (0·9 mm.) and smaller pores (0·15 to 0·25 mm.) than the type, and slightly thicker walls, with neither squamulae nor spines well developed, and with somewhat less crowded tabulae, which are only very infrequently suspended from squamulae.

Melb. Univ. 1969 and 1962, from Caves Road quarry, Buchan, and G.S.V. 48436 from the Murrindal beds (Loc. 230) are all fairly close to the type specimen, and B.1 from Bindi, No. 1963 in the Melb. Univ. collection, is also attributable to the *F. bryani* plexus.

F. bryani may well have given rise to *F. pluteus* sp. nov.

Favosites pluteus sp. nov.

(Pl. VIII, figs. 25, 26)

? *Favosites squamulifera* Etheridge, 1899, p. 166, pl. XXXVIII, figs. 4, 5. 'Tamworth.' Exact horizon and locality unknown; on lithology, Etheridge considered the type specimens (now missing from the Australian Museum) to be from the Woolomol Limestone.

Holotype. G.S.V. 48573, upper part of Murrindal beds, Rocky Camp, Buchan (Loc. 144) (Pl. VIII, figs. 25a-d).

Diagnosis. Corallum massive, with larger corallites 1 to 1·1 or 1·25 mm. in diameter, and with numerous wide flat shelf-like squamulae which do not vary in thickness or width from base to free edge, but project horizontally from the wall, and are frequently without close relationship to mural pores; pores uniserial, 0·25 mm. in diameter and 0·4 mm. from centre to centre. Septal spines occur near the angles of the corallites. Tabulae difficult to distinguish from the squamulae, 11 in 5 mm.

Description. The corallum is massive, the corallites being unequal, usually from 1 to 1·25 mm. in diameter. They are polygonal, usually 5- or 6-sided; the walls are about 0·1 to 0·14 mm. thick. There is in almost every intertabular space at least one wide shelf-like plate, often more than half the width of the lumen, often lying parallel to the tabulae or sometimes inclined upwards from the wall or showing a very flat curvature. These project from the wall, with the inner edge free. They are not always related to the pores, nor are they always in pairs on opposite sides of the same common wall. They do not thicken or widen towards the base, and so are different from the eaves-like squamulae in *F. bryani*. The pores are round or very slightly elongated vertically, and about 0·25 mm. in diameter; they may be as close as 0·4 mm. from centre to centre, but are often a little wider apart. They are frequently closed by pore plates, as in *F. nitidus*, *F. bryani* and *F. stelliformis*. The tabulae are flat, and strong, meeting the walls markedly at right angles; they are thick, and are crowded in some zones of the corallum; in other zones they are distant. Septal spines may project from the walls near the angles.

Occurrence. This species occurs also at Heath's Quarry, Buchan, and at Murindal. I also have from Taemas, N.S.W., a specimen similar to those from Murrindal; in these the shelf-like squamulae are less frequent than at the type locality; there are a number of places where the squamulae are opposite on either side of the common wall; but there is little or no inclination in the squamulae, and little or no increase in thickness from free edge to walls. The Murrindal and Taemas specimens thus suggest transition from *F. bryani*.

Remarks. F. spinigera is described by Chapman as possessing spines thick at the base, and sharply pointed and curved squamulae; in *F. pluteus* the squamulae and spines are horizontal, and evenly thickened from base to edge. The squamulae in *F. pluteus* are flat and wide, only exceptionally curved.

Genus **Gephuropora** Etheridge; Jones, 1941, p. 51

Gephuropora duni Etheridge; Jones, 1941, p. 54

(Pl. VIII, figs. 27a, b)

Remarks. The following specimens in the Geological Survey of Victoria collection from the Couvinian Murrindal beds belong to the species: 48485, upper reef limestone, Loc. 225; 48461, Loc. 222; 48480, in reef facies in valley S.E. of Sandy's Homestead, about 800 feet above base of Buchan Series; 11778 (slides 4240, 4241) and 11768 (slide 4227), from the Buchan-Gelantipy road at Dickson's, Murrindal, opposite allot. 25B, Sec. 52; 11677 (slides 4234-6), No. 2 locality, Buchan, from a new road cutting from Buchan township to the Spring Creek Caves; the road forms the north boundary of allots. 10 and 18, Parish of Buchan.

The only foreign occurrence of *Gephuropora* is in the lower and upper Couvinian of the Ardennes. Bassler (1944, p. 42) has recently brought together scattered references to Favositidae with occasional small tubules. The Buchan material is insufficiently well preserved for studies on the wall tissue of the small tubules, such as might be expected to give evidence on whether they are corallites formed by modified polyps or whether they are due to symbiotic or parasitic growth. It should be observed that the characters of *G. duni* are, except for the tubules, very close to those of the *Favosites goldfussi* group.

Genus **Thamnopora** Steininger, 1831

Genotype. T. madreporacea Steininger, 1831, p. 11, Middle Devonian. Eifel = *Alveolites cervicornis* de Blainville, 1830, p. 370—see Lang, Smith and Thomas, 1940, p. 133.

Diagnosis. Ramose Tabulate corals in which the cylindrical branches may be flattened and coalesced; the corallites are typically polygonal and diverge from the axis of the branch and usually open normal to the surface; the corallite walls are dilated throughout, and the dilatation increases distally; typically the growth lamination in the sclerenchyma of the wall is obvious, while its fibrous nature is not; septal spines are usually obsolete and mural pores are large.

Range. Rather rare in the Silurian of Europe, very common in the Devonian of Europe, Asia, Australia, North America and Morocco; not known with certainty from the Lower Carboniferous, but again common in the Artinskian of Timor, India, Australia and North America, when it may show dimorphism of corallites; rare in the Triassic.

Thamnopora alterivalis (Chapman)

(Pl. VIII, figs. 28a, b)

Pachypora alterivalis Chapman, 1914, p. 309, pl. LVII, figs. 28, 29, Deep Creek, Thomson River, Gippsland. Devonian.

Holotype. Nat. Mus. 12925 (MD562), Deep Creek, Thomson River, Victoria (Devonian).

Diagnosis. Ramose *Thamnopora* with slender, finger-like branches 3 to 7 mm. in diameter, with little dilatation except distally and with few mural pores.

Description. The corallum is ramose and fasciculate, the branches being slender and cylindrical or somewhat flattened, 3 to 7 mm. in diameter, and in the Cave Limestone specimen G.S.V. 47708 (from Loc. 79) spaced from 2 to 7 mm. apart;

they are fairly regular in direction of growth, parallelism being not very marked; the branches divide dichotomously and diverge only gradually.

The individual corallites are polygonal, and attain a maximum diameter of 0·7 mm., though most are smaller, about 0·4 or 0·5 mm.; some of them are very long, growing upward and but slightly outward from the axial region for 18 mm. and then, in the last 0·5 or 1 mm. of their course, turning to open in a calice at right angles to the axis of the branch. Dilatation of the walls is small, but increases gradually distally; the walls of the actual calice above the topmost tabula of each corallite thicken more suddenly, and end in a somewhat swollen rim. The walls consist of fibres arranged at right angles to the median dark line; and in the calical parts of some corallites traces of growth lamellation are visible.

Mural pores are developed in a single series in the middle of the faces of the corallites; they are small, circular, and not common. No septa or septal spines have been observed; the tabulae are complete, horizontal or slightly concave, somewhat irregularly spaced, more crowded near the calices, and up to 2 mm. apart in the axial regions of the corallite.

Occurrence. This species is now recognized from two localities in the Buchan district, in addition to the type locality, Deep Creek. These are in the Cave Limestone (Loc. 79) and in the nodular limestone of the lower Murrindal beds of Loc. 123; the three branches shown in this younger specimen (G.S.V. 47846) are 5 mm. in diameter.

Remarks. This species closely resembles *T. reticulata* (de Blainville) of the European Devonian, which Lecompte's admirable study (1939) diagnoses as typically fasciculate, with compressed or cylindrical branches to 12 mm. wide, and shallow, rounded and unequal calices 1 to 1·5 mm. in diagonal. Below the surface the corallites are polygonal, and turn sharply to open at right angles to the axis, with considerable thickening distally; with no septal spines and with mural pores 0·16 to 0·2 mm. in diameter in one series, 0·5 to 0·6 mm. apart. Lecompte has discerned a very slow continuous evolution in the group from Couvinian to the top of the Frasnian; in general, the higher the stratigraphical horizon the wider the corallites and the thicker the walls. The Victorian species could well be related to *T. reticulata*; the smaller diameter of its corallites and the smaller degree of thickening it shows may indicate that it is older than the upper Couvinian, Givetian and Frasnian specimens studied by Lecompte. Our species, however, shows a relatively much narrower external zone in which the corallites are at right angles to the axis and have markedly thicker walls, and for this reason it seems well to distinguish it from the European. *T. orthostachys* Penecke, 1894, p. 607, pl. X, figs. 7, 8, from the Emsian *barrandei* beds of Graz, Austria, has some similarities to our form, but is slightly larger, with somewhat thicker walls.

Thamnopora angulata sp. nov.

(Pl. IX, figs. 29, 30)

Holotype. G.S.V. 48507, upper Murrindal beds, upper reef limestone, Loc. 225, Couvinian.

Diagnosis. Dendroid *Thamnopora* with delicate branches 4 mm. in diameter, with corallites about 0·3 mm. in diameter, turning sharply outwards at the edge of a narrow axial region, directed to and opening at the surface at about 45°; the walls of the corallites thicken and the corallites widen distally to a diameter of 1·5 mm.; septal spines and tabulae are few, and mural pores small and distant.

Description. The corallum is branching, with slender branches 4 or 5 mm. in diameter, dividing dichotomously but not always in the same plane. In the holotype dichotomy occurs at fairly regular distances of 12 or 13 mm.; and the products diverge at an angle of about 30°. There is a fairly well marked division into an axial and an outer region. The axial region is about 1 mm. in diameter; in it the corallites proceed almost vertically, are about 0·3 mm. in diameter, and have common walls about 0·2 mm. thick. At the edge of this axial zone they turn sharply outwards and proceed to the surface at an angle of about 45°, their course in this outer zone being straight or only slightly curved; they increase in diameter and when they open at the surface they are slightly elongated in a vertical plane, 1 to 1·5 mm. in diameter; the openings are a little oval and separated by common walls 0·3 to 0·5 mm. thick. Septal spines are frequent, and tabulae have not been definitely identified; mural pores are round and small, 0·1 mm. in diameter and rather distant. The walls are formed of fibres directed outwards from the median dark line.

Remarks. This species is perhaps closest to the long-ranged *Thamnopora polyforata* described as *T. dubia* by Lecompte (1939, p. 120) from the upper Couvinian and Givetian of the Ardennes, which merges in the Frasnian of the Ardennes into *T. boloniensis*; it differs in its sharper distinction into axial and outer zones, and in its calices being elongated vertically rather than transversely. *Thamnopora meridionalis* Nicholson and Etheridge from the Givetian Burdekin limestone of North Queensland seems also to belong to the *polyforata* group, which has been recognized by Smith (1945, p. 64) in the Frasnian of Arctic Canada.

Localities. The species is found also at an unknown location and horizon in the Wellington district, N.S.W., but here the branches are somewhat more slender, 3 mm. rather than 4 mm., and may be reticulate, the growing point of one branch coalescing with its neighbour. A number of fragments found in the lower Murrindal beds of the South Buchan limestone quarry possibly belong to this species, although the diameter of the branches is less, 3 mm. at most, the corallites are of smaller diameter, and some tend to turn at right angles to the axis before opening at the surface.

Thamnopora tumulosa sp. nov.

(Pl. IX, figs. 31a-d)

Holotype. G.S.V. 48324, lower Murrindal beds, Loc. 183, Buchan district, Couvinian.

Diagnosis. Thamnopora with irregular branches up to 10 mm. in diameter, new growth sometimes encrusting old; with eight to twelve broad low septal ridges developed in the unequal calices, which are from 1 to 2 mm. in diameter; with occasional spines projecting into the lumen, and a few small mural pores, 0·1 to 0·2 mm. in diameter.

Description. The corallum is ramose, the branches being about 10 mm. in diameter, or smaller. One thin section shows an encrustation of a branch by new growth, which is relatively thin-walled. The corallites are unequal and polygonal, and curve rapidly outwards from an apparently excentric axis, to open at the surface either obliquely or, after a sudden change of curvature, at right angles. The larger corallites may attain a diagonal of 2 mm. at the surface; but most corallites are smaller, between 1 and 2 mm. In the axial parts of the branch the corallite wall is only moderately thick, there being about 0·25 mm. or less of fibrous

tissue between the lumina of adjoining corallites; the walls are equally thin in the encrustations of new growth on the branches. As the corallites diverge towards the surface of the branch their lumina increase slightly in diameter, but the common wall between them is greatly thickened up to 1 mm. In transverse sections of individual corallites, just below the calices, the common wall between two corallites shows a median dark line by transmitted light, and a median white line by reflected light; this represents the original position of contact of the polyps of two adjoining corallites at that calical level; projecting from this median line into each lumen is a thick hummocky ring of coral tissue, arranged in eight to twelve hummocks, each hummock representing a broad low septal ridge.

In most corallites the $CaCO_3$ of this ring is opaque and cannot be resolved into constituents; during the preparation of the thin section, cracks have frequently developed, parallel to the inner edge of the ring, curving outwards in the hummocks; sometimes perpendicular cracks have developed, separating one hummock from its neighbours. They seem to have followed original separation planes. In a few corallites one or two of the hummocks in the ring can be seen to be formed of fibres directed inwards and sideways from the mid-line of the hummock, so that each hummock would seem to represent the growth of one vertical series of trabeculae; occasionally the trabeculae have been reduced to the holacanthine condition during recrystallization. Sporadically one of the monacanths projects some distance into the lumen, appearing as a horizontal or slightly upwardly directed spine, sometimes a little spur-shaped, and tending to be elongated in the vertical plane. Where two or more such spines are seen above one another in series, which is rare, the distance between their axes is about 0·2 mm.

My interpretation of the structure of the stereozone is that it is formed of a small number (eight to twelve) of vertical ridges (septa), each consisting of one series of vertically superposed monacanths, the average spacing being about 0·2 mm. Usually the stereozone is developed to the full length of the monacanths, but occasionally the growing points of these project into the lumen.

The mural pores are small, 0·1 to 0·2 mm. in diameter; in the distal parts of the corallites they form narrow cylindrical spaces through the stereozones, at right angles to the median line between corallites. Tabulae are few, usually sagging, and irregularly spaced.

Remarks. The generic position of this species is a matter for discussion. *Striatopora,* with the Silurian genotype *S. flexuosa,* has a stereozone only in the periaxial parts of the branch, whereas *Thamnopora,* with the Devonian genotype *T. cervicornis,* has its stereozone throughout, narrow at first in the axial region, but gradually increasing in width distally. In *Striatopora* the stereozone is formed by a large number of vertical ridges each consisting of one series of vertically superposed trabeculae which are reduced to the holacanthine condition, thin, clear, recrystallized axes being surrounded by dilating tissue in which recrystallization has emphasized the growth lamellation rather than the fundamental fibres. In septal structure, then, our species differs from *Striatopora* only in degree, but in this very degree it approximates to *Thamnopora* in which also traces of the individual trabeculae are seldom discoverable. Since our species has the stereozone gradually increasing distally as in *Thamnopora,* it is included in that genus in preference to *Striatopora,* leaving for that genus those species whose septal trabeculae are typically clearly shown and in the holacanthine condition, and in which there is a sudden marked development of the stereozone in the periaxial corallites.

Family AULOPORIDAE Nicholson; Lecompte, 1939, p. 175

Genus **Aulopora** Goldfuss; Lecompte, 1939, p. 175

Aulopora cf. **conglomerata** Goldfuss (1829, pl. XXIX, fig. 4)

(Pl. IX, fig. 32)

For figure and description of *A. conglomerata* Goldfuss see Lecompte, 1936, p. 83, pl. XLII, fig. 2.

? *Syringopora auloporoides* de Koninck, 1876, p. 76, pl. III, fig. 1.

The type material was a single specimen found at Moara Creek, to the north of Tamworth, associated with *Alveolites subaequalis* Edw. and H., in bright grey dolomitic limestone. W. S. Dun considered it possible that this is the locality now known as Moore Creek, but pointed out that Attunga Creek, a few miles to the north of Moore Creek, is called Mooar Creek on an old Colony Map. The specimen was involved in the Garden Palace fire in Sydney in 1882 and has not been recovered. Etheridge (1899, p. 174, pl. XXVIII, figs. 1, 2) applied the name *S. auloporoides* to straggling coralla with corallites 1 mm. in diameter from the Woolomol limestone of Par. Woolomol, near Tamworth, and the Moore Creek limestone of Moore Creek, near Tamworth.

Description of Victorian Couvinian specimens G.S.V. 48827 and 48879 (Loc. 255), 47430 (Loc. 7), from the Cave limestone, and 48698 (Loc. 237) from the Murindal beds 20 ft. above the Cave limestones. The corallum consists of a series of straggling, irregularly directed branches, sometimes adherent one to another or to other corals, or shells. The branches each consist of numerous short corallites about 3 mm. long, each corallite giving rise to another by cladochonoid increase; when not infrequently one corallite gives rise to two others by cladochonoid increase, each of the products may continue the increase, with the result that the branch consists of from one to three cladochonoid series; in such cases the series are adherent one to another. The calices open at an angle to the stem, rising 1 mm. above it, and having a diameter of about 1 mm. The proximal parts of the corallites (below the issue of the new corallite) is smaller. No lateral tubules connecting one stem to another have been observed. The epitheca is usually smooth, neither transverse growth striation nor vertical rugae being visible. In transverse section there is seen to be a moderately thick peripheral stereozone (0·2 mm.), and occasional traces of septal spines have been noted. The tabulae are concave or infundibuliform.

Remarks. The similarity in growth form between these individuals and the European Middle Devonian *A. conglomerata* is striking; our forms, however, do not show the longitudinal striation observed on the European forms.

It would appear from Etheridge's descriptions of the Tamworth specimens he used to rehabilitate de Koninck's name *S. auloporoides* that they are close to our Victorian forms; but I do not consider it possible that our Buchan specimens can belong to the same species as de Koninck's figured type specimen, for de Koninck includes in his description a reference to vertical growth of the offsets never exceeding 3 centimetres. As our offsets never exceed 2 mm. it seems that too great a difference is represented for one species.

Family SYRINGOPORIDAE

Genus **Syringopora** Goldfuss, 1826

Genolectotype (chosen Edwards and Haime, 1850, p. LXII; see Lang, Smith and Thomas, 1940, p. 130): *S. ramulosa* Goldfuss, 1826, p. 76, pl. XXV, fig. 7. (Carboniferous' 'aus dem Uebergangskalk von Olne in Limburgischen', Germany.

Diagnosis. Compound corals with cylindrical separated corallites, typically joined by connecting tubules; with thickened walls and with septa represented by irregularly developed spines curving upwards and inwards from the wall; with tabulae deeply sunken axially, forming a syrinx-like inner tube.

Range. The genus has an extremely long range from Caradocian to Permian.

Syringopora flaccida sp. nov.

(Pl. IX, fig. 33)

Holotype. G.S.V. 48878, Loc. 255, Cave Limestone.

Diagnosis. Straggling coralla with corallites up to 4 mm. in diameter, very irregular in direction and plane of growth, without connecting tubes, but occasionally adherent one to another; increase lateral, with offsets at first up to 2 mm. in diameter, old and new corallites continuing growth. Tabulae infundibuliform.

Description. The corallum is dendroid and straggling; the corallites are up to 4 mm. in diameter, with faint vertical rugae and transverse growth striation; their direction and plane of growth is very irregular, and they twine somewhat, occasionally becoming adherent one with another. No lateral connecting tubules have been observed, nor do mural pores appear to be developed at the point of contact. Increase is lateral, and not frequent; the offset begins with a diameter of less than 2 mm., and slowly expands to a maximum diameter of 4 mm.; the old corallite continues to grow after the production of the offset. Slender septal spines may occasionally be distinguished in or projecting slightly from the peripheral stereozone, which is 0·2 mm. or less in width. The tabulae are infundibuliform, but not regularly so, some plates occurring like lonsdaleoid dissepiments. The syrinx is irregular and not central.

Remarks. The species differs from the genotype of *Syringopora* and resembles that of *Aulocystis* in its straggling growth and in the apparent absence of connecting tubules. It differs from the European Givetian type species of *Aulocystis* Schluter (1885, p. 148), however, in the continued growth of the old corallite after lateral increase and is consequently placed in *Syringopora*. Arrest of the growth of the old corallite almost immediately after increase is characteristic of both *Cladochonus* and *Aulocystis*. *S. porteri* Etheridge from the Givetian Moore Creek limestone of Tamworth, N.S.W., has a similar growth habit, but its corallites are only 1½-2 mm. in diameter and have relatively much thicker walls.

Localities. In addition to specimens from the type locality, the following have been examined from the Buchan district: G.S.V. 48430 (Loc. 7); Melb. Univ. 1966, B. Ripper Coll., Spring Creek; Melb. Univ. 1965, Caves Reserve; all from the Cave Limestone; Melb. Univ. 1967, four specimens collected by B. Ripper from Citadel Rocks, Murrindal R., from an undetermined horizon; and Melb. Univ. 1964, from an unknown locality and horizon in the Murrindal district.

Syringopora sp.

(Pl. IX, figs. 34a, b)

One specimen, G.S.V. 48479 (Loc. 222) from the upper reef limestone of the upper Murrindal beds of the Buchan district, Victoria, Couvinian, has corallites of 2 mm. diameter, unequally spaced (2 to 4 mm.). Connecting tubules about 7 mm. in diameter occur, but some at least of these are of a somewhat unusual type; they proceed at right angles to the corallite from which they issue until they are almost

touching a neighbour; they then suddenly turn upwards to develop as a new corallite. It was not proved, with the single specimen available, that all connecting tubules were of this type; some may have been similar to those of the genotype of *Syringopora*, by which the axial spaces of the neighbouring corallites were placed in continuity. Sections show corallites and tubules to possess a thick peripheral stereozone (0·5 mm. wide), in which holacanthine septal spines appear, directed inwards and slightly upwards. The vertical corallites possess tabulae, sometimes thickened, usually infundibuliform with the necks of the funnels forming a syrinx, sometimes crossed by small flat plates. No tabulae have been observed in the horizontal tubules.

Genus **Roemeria** Edwards and Haime, 1851; see Lecompte, 1936, p. 74

Genoholotype. *R. infundibuliformis* (Goldfuss) Edwards and Haime, 1851, pp. 152, 253, = *Calamopora infundibulifera* Goldfuss, 1829, p. 78, pl. XXVII, figs. 1a, b. Middle Devonian, Eifel district and Bensberg, Germany; see Lang, Smith and Thomas, 1940, p. 116.

Diagnosis. Basaltiform or sometimes partly fasciculate Tabulate corals; corallites with peripheral stereozone, with septal spines directed inwards and slightly upwards, with infundibuliform tabulae forming an excentric syrinx within the lumen; and with mural pores through which the syrinxes of neighbouring corallites are placed in continuity.

Range. Niagaran of North America, Upper Silurian of Scotland, Middle Devonian of Europe and Australia.

Remarks. There are several Australian Devonian species with the above diagnostic characters. Two of these have been previously described as *Michelinia progenitor* Chapman, 1921, p. 220, pl. IX, figs. 7, 8, from [the Middle Devonian of] Lilydale, Victoria, and *Syringopora thomii* Chapman, 1921, p. 222, pl. X, fig. 14, from [the Lower or Middle Devonian of] Loyola, near Mansfield, Victoria. The first of these has polygonal corallites in contact, with diameter from 2·5 to 3·5 mm.; the second has corallites sometimes polygonal and in contact, sometimes cylindrical, with a diameter from 4 to 5 mm. Two other species are described in this paper—both with corallites sometimes polygonal and in contact and sometimes cylindrical. One of these, *R. ocellata*, has corallites 6 mm. in average diameter, and the other, *R.* sp., 3 mm. All these Australian forms have a remarkable horizontal wrinkling of the corallites, which causes very rapid changes in diameter of the corallites, and involves the peripheral stereozone; this is most clearly developed where the corallites are cylindrical, and the wrinklings are freely developed in the interspaces between corallites; but it is also visible in the tortuous walls of polygonal contiguous corallites. Whether the character distinguishes these Australian species from the European genotype I cannot at present determine, owing to lack of European material for comparison.

In the way in which the axial syrinxes of neighbouring corallites are placed in communication by the mural pores, this genus resembles *Syringopora*, where the connecting tubules perform the same function; this suggests that the two are closely related.

The Gotlandian species *R. kunthiana* Lindstrom (1896) has been compared by Tripp (1933, p. 130) with *Favosites forbesi*, while Lecompte doubts the propriety of referring it to *Roemeria*. The Niagaran genus *Syringolites* Hinde may be distinct from *Roemeria*, but figures are required.

Roemeria ocellata sp. nov.

(Pl. IX, figs. 35a, b)

Holotype. Melb. Univ. 1955, slides 642 and 643, from the upper Murrindal beds (Couvinian) of Rocky Camp, Buchan, Victoria.

Diagnosis. Roemeria with large corallites (average diameter 6 mm.), sometimes prismatic, sometimes cylindrical, with horizontal expansion wrinklings involving the relatively narrow stereozone; septal spines numerous, discrete; mural pores sparse.

Description. The corallum is large, mainly cerioid, with corallites in contact and prismatic, but in patches the corallites are free and cylindrical. The average corallite has a diameter of 6 mm., but 7 mm. is sometimes observed. Transverse expansions like large wrinklings occur about 4 or 5 mm. apart in the corallites, tending to bridge the gap where corallites are not in contact, and wrinkling the common wall where they are.

The common wall between corallites is about 0·5 mm. thick, half being contributed by each corallite. Short, sharp, straight spines project from the inner edge of this wall, directed slightly upwards. They are about 0·1 mm. in diameter, and may proceed through several tabulae towards the axis. Other small spines may be developed on the upper surface of a tabula, and may then sometimes extend towards the axis through one or more other tabulae. The spines are developed in not very regular vertical series about 0·4 mm. apart, one row of spines to each series, in which the individual spines are 0·3 mm. apart; but the regularity is not great. The spines are usually seen even in the axial tube.

The tabulae are thin and crowded; they are long and steeply inclined, forming a series of incomplete and irregular cylinders enclosing a wide and irregular axial tube formed by the innermost tabulae abutting on those immediately below, and usually laterally compressed; there are nine nearly parallel sections of plates to be seen between the wall and the axial tube in a corallite 6 mm. in diameter. Mural pores are large and rather scarce, but wherever they occur the axial tubes of neighbouring corallites are continuous through the pore by means of a lateral tubule formed by the addition of the edges of the tabulae to the wall in the zone surrounding the mural pore.

Remarks. This species possesses the largest corallites of all the known *Roemeria*. The transverse wrinklings, while characteristic of all Australian *Roemeria*, have not been described in European species.

Roemeria sp.

(Pl. IX, figs. 36a, b)

G.S.V. 47767 (Loc. 97) from the Cave Limestone differs from other Australian *Roemeria* in size of corallite and apparently in the large number of cylindrical corallites; but the material available at present is unsuitable for the foundation of a new species.

Diagnosis. Partly cerioid *Roemeria* with corallites 3 mm. in average diameter, with transverse wrinklings of the peripheral stereozone, which is 0·3 to 0·5 mm. wide.

Description. The corallum is partly cerioid and partly phaceloid, the corallites are cylindrical when not in contact, with small transverse wrinklings involving the peripheral stereozone; when they touch, the younger corallites accommodate them-

selves to the cylindrical form of the older corallites. The average diameter of older corallites is 3 mm., but in the only Victorian specimen most corallites were younger and smaller. The peripheral stereozone of each corallite is 0·3 to 0·5 mm. wide, and in it may be seen septal spines in a holacanthine condition, piercing a base of lamellar sclerenchyme; the spines project upwards and inwards only about 0·1 mm. from the stereozone, but others of a similar length develop on the upper surfaces of the tabulae. The tabulae are developed in two zones. The outer zone consists of large plate-like lonsdaleoid dissepiments, with long, convex inner surfaces, the lower edges of younger plates resting on the inner, upper edges of older plates; new plates tend to develop fairly evenly above the old; the marginal region of each corallite as seen in a transverse section may be divided into two to four areas by two to four such plates. The inner zone, about 0·5 mm. wide, is crossed by small saucer-like tabellae; it is seldom developed exactly in the centre of a corallite, and is usually not circular but elongate in transverse section.

Remarks. A specimen, Univ. Q'ld. F.10273, from Wellington, N.S.W., may belong to the same species as this Victorian specimen; its corallites, however, are polygonal rather than cylindrical and suggest that the two specimens may be related to *R. progenitor* (Chapman).

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Locality List for C. Teichert's Collection, Buchan-Murrindal District

(Horizons are as given by Dr. Teichert)

3. Nodular limestone in cutting of old road to South Buchan, $\frac{1}{4}$ mile south of Buchan (below Station 32); lower Murrindal beds.
7. Slope west of Fairy Creek, opposite Fairy Creek cave, about 50 ft. above bottom of creek; very low in Cave limestone.
13. Near top of Cave limestone, top of hill above Police Station, Buchan (near Station 37); near top of Cave limestone.
36. Along section of Cave limestone measured just south of southern boundary of Cave Reserve, 597 ft. above base of section; near top of Cave limestone.
55. Gelantipy road about 30 chains north of 34 (i.e., Gelantipy road about 60 chains east of big hairpin bend near Buchan (Station A9). Station A32. Murrindal beds, 850 ft. above *Gyroceratites* bed.
79. Fifty-three chains along Moon's road from corner of Orbost, Basin and Moon's roads; Cave limestone, upper part.
82. Small reef in Cave limestone in corner between Basin and Orbost roads near Station 87 (Station 94); upper part of Cave limestone.
96. About $27\frac{1}{2}$ chains along Orbost road from corner of Orbost, Basin and Moon's roads; upper part of Cave limestone.
97. Seventy links east of Loc. 96; upper part of Cave limestone.
123. = Loc. 3.
145. Gelantipy road north of Buchan, first anticline on eastern limit near axial region (Station A22); lower Murrindal beds, just below *Gyroceratites* beds.

156. Gelantipy road north of Buchan, axial part of first anticline; lower Murrindal beds.
167. ½ mile (28 chains) north of Buchan R. bridge; beds with *Gyroceratites desideratus* in lower Murrindal beds.
177. Section of ridge east of McLarty's Homestead, 1395 ft. above porphyry; upper part of reef limestone complex of Murrindal beds.
183. Gelantipy road north of Buchan about 28 chains east of hairpin bend, a little above the horizon with *Gyroceratites desideratus*; lower Murrindal beds.
190. About ¾ mile west-north-west of Rocky Camp; somewhere in middle of Murrindal beds.
222. Gully south-east of Sandy's Homestead, 800 ft. above Porphyry series (probably somewhat higher); upper reef limestone, upper Murrindal beds.
225. Close to boundary fault, due west of Sandy's Homestead; upper reef limestone within the upper Murrindal beds.
230. On road at head of gully and immediately north of Sandy's Homestead; upper reef limestone, upper Murrindal beds.
233. Near base of Stromatoporoid reef, ½ mile west of Murrindal School; low in Murrindal beds, probably not more than 3-400 ft. above Cave limestone.
237. On road just south of Murrindal School; lower Murrindal beds 20 ft. above the Cave limestone.
255. Gordon Hodges Gully, one chain from edge of porphyry; Cave limestone.

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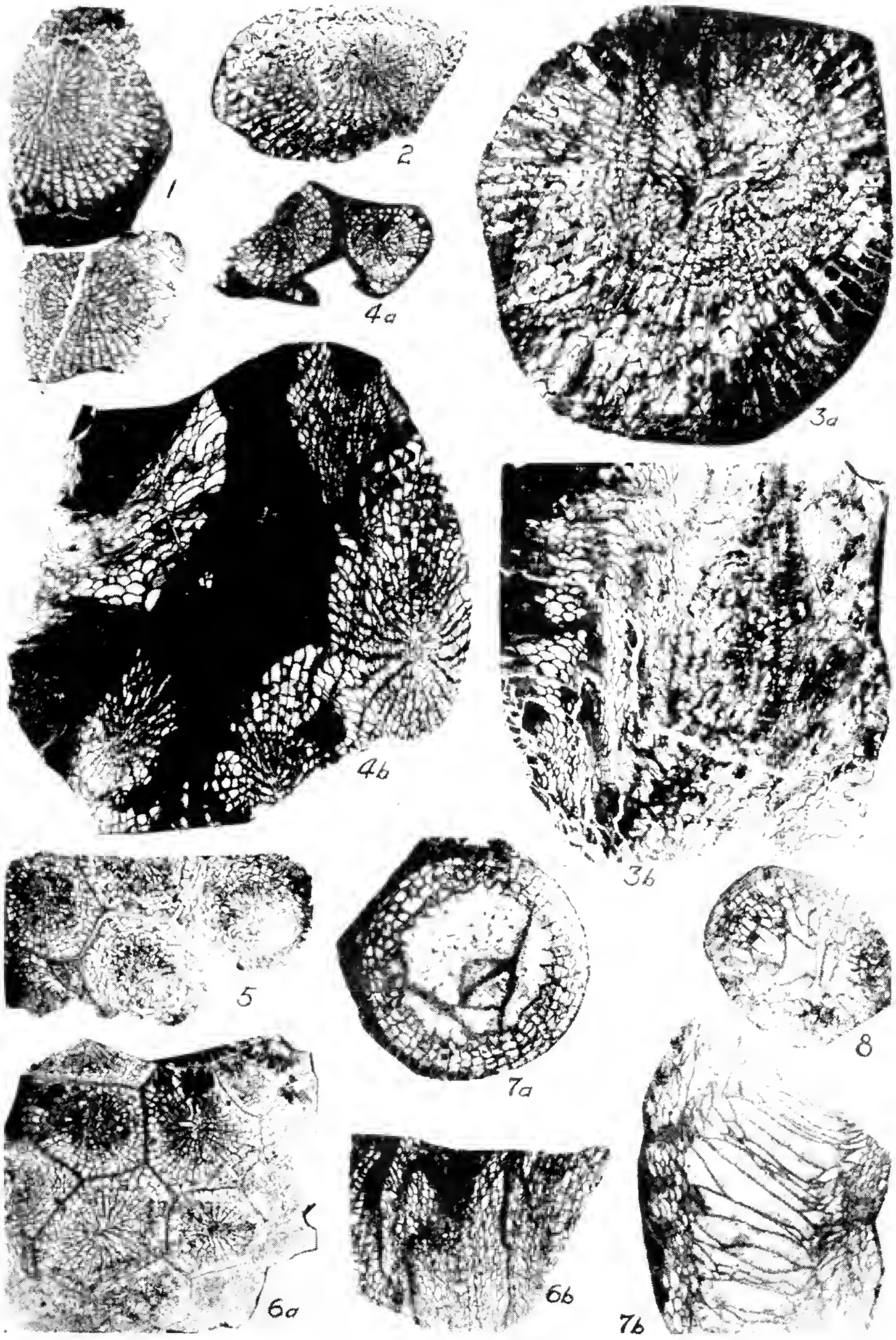
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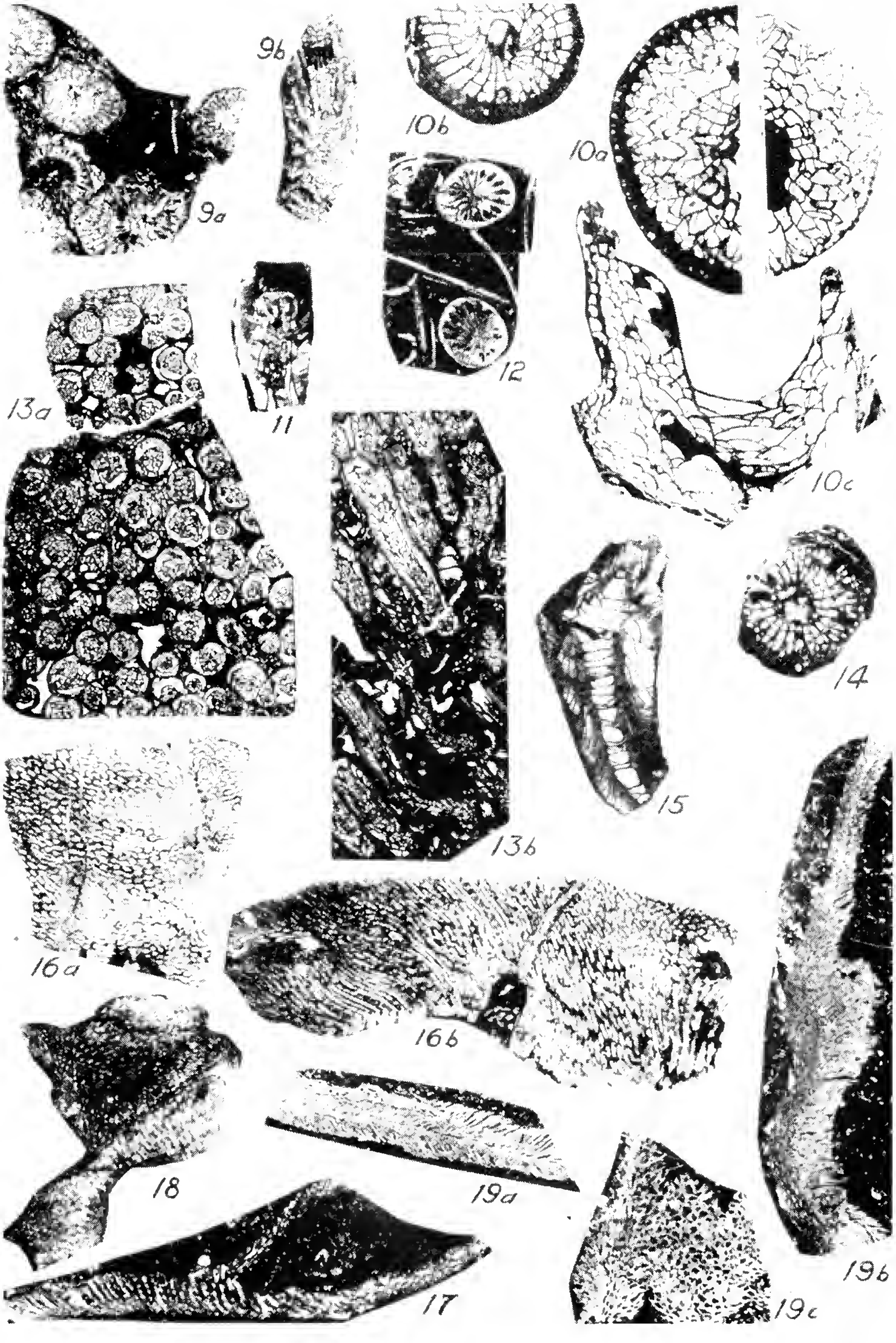
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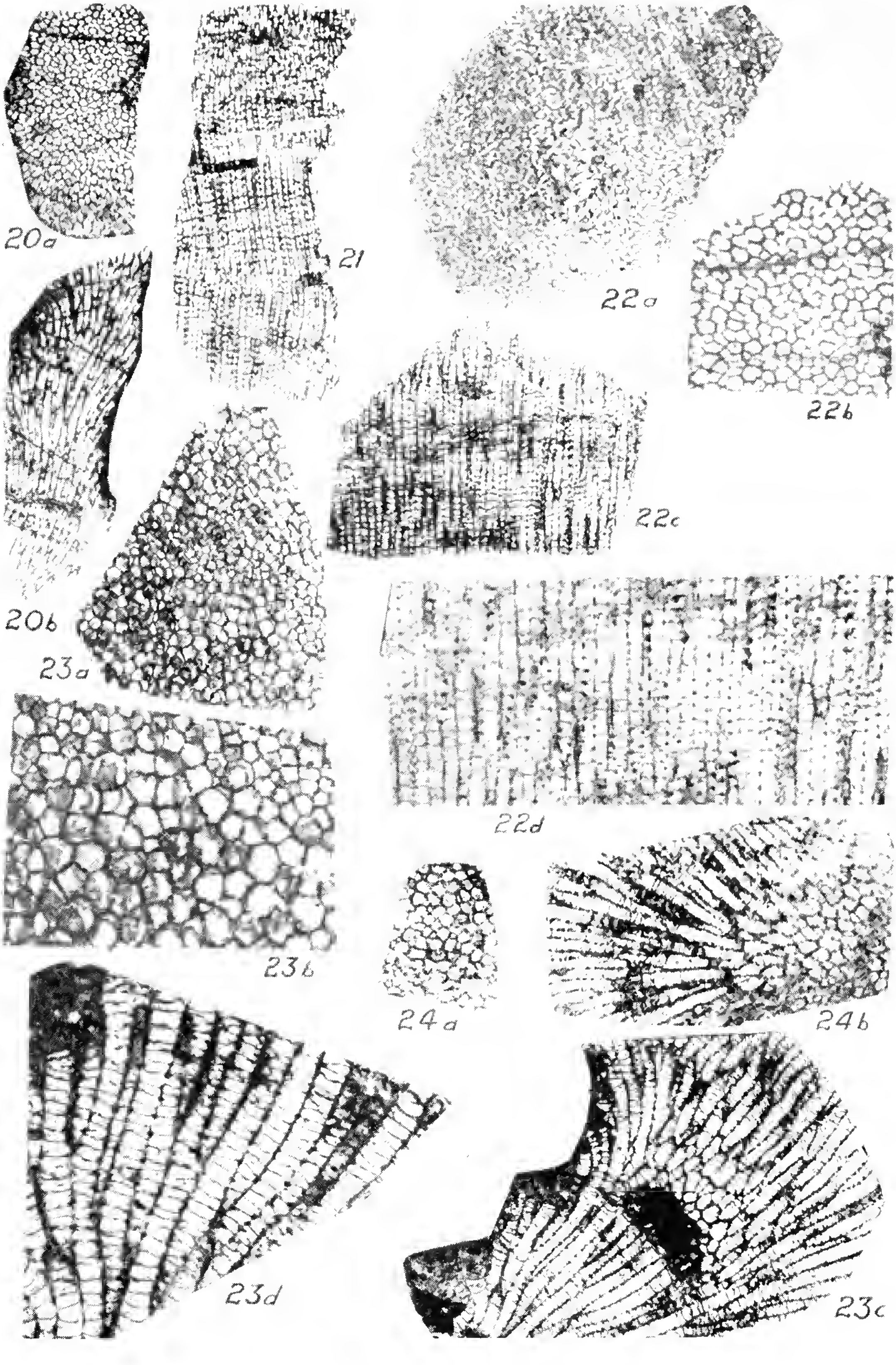
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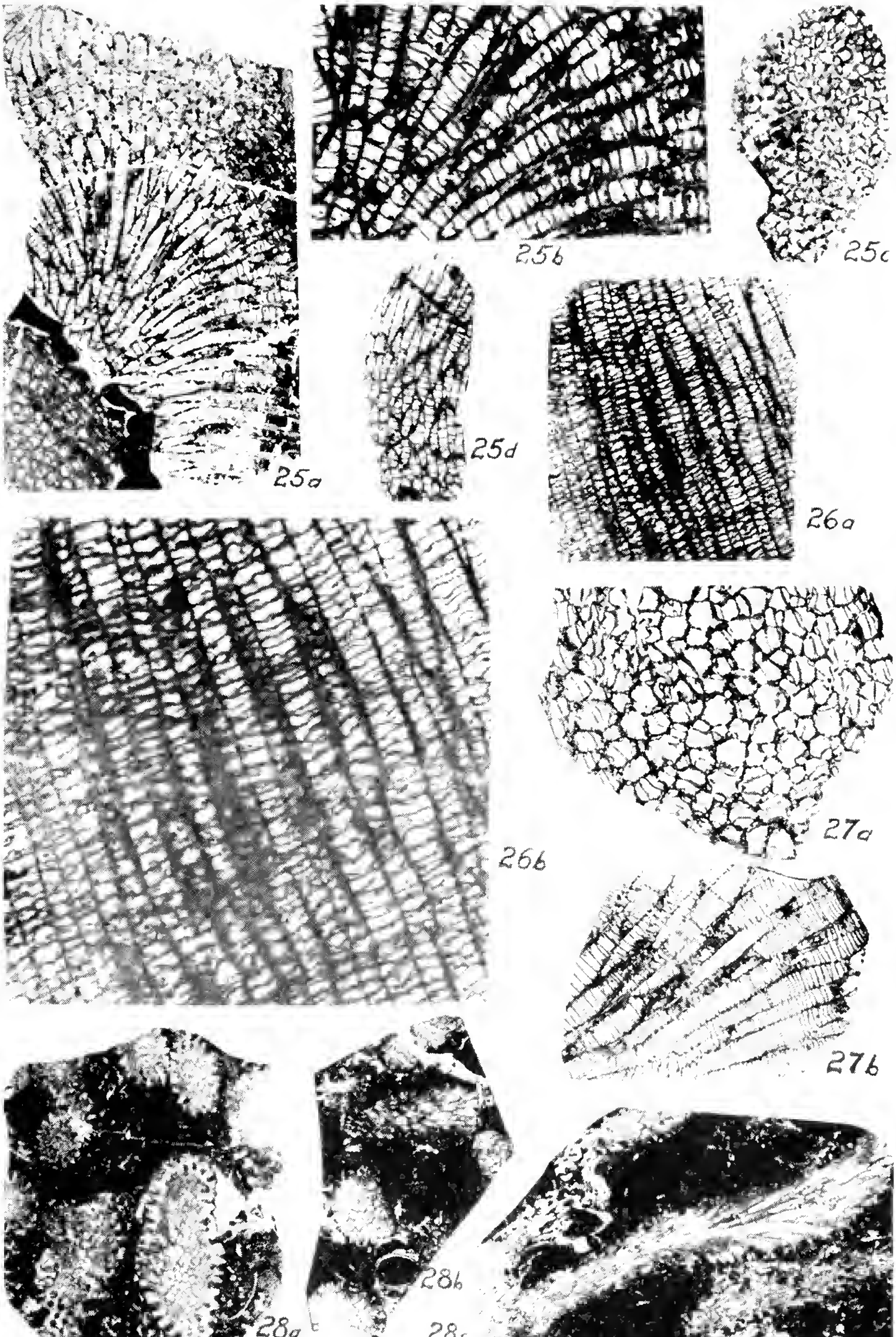
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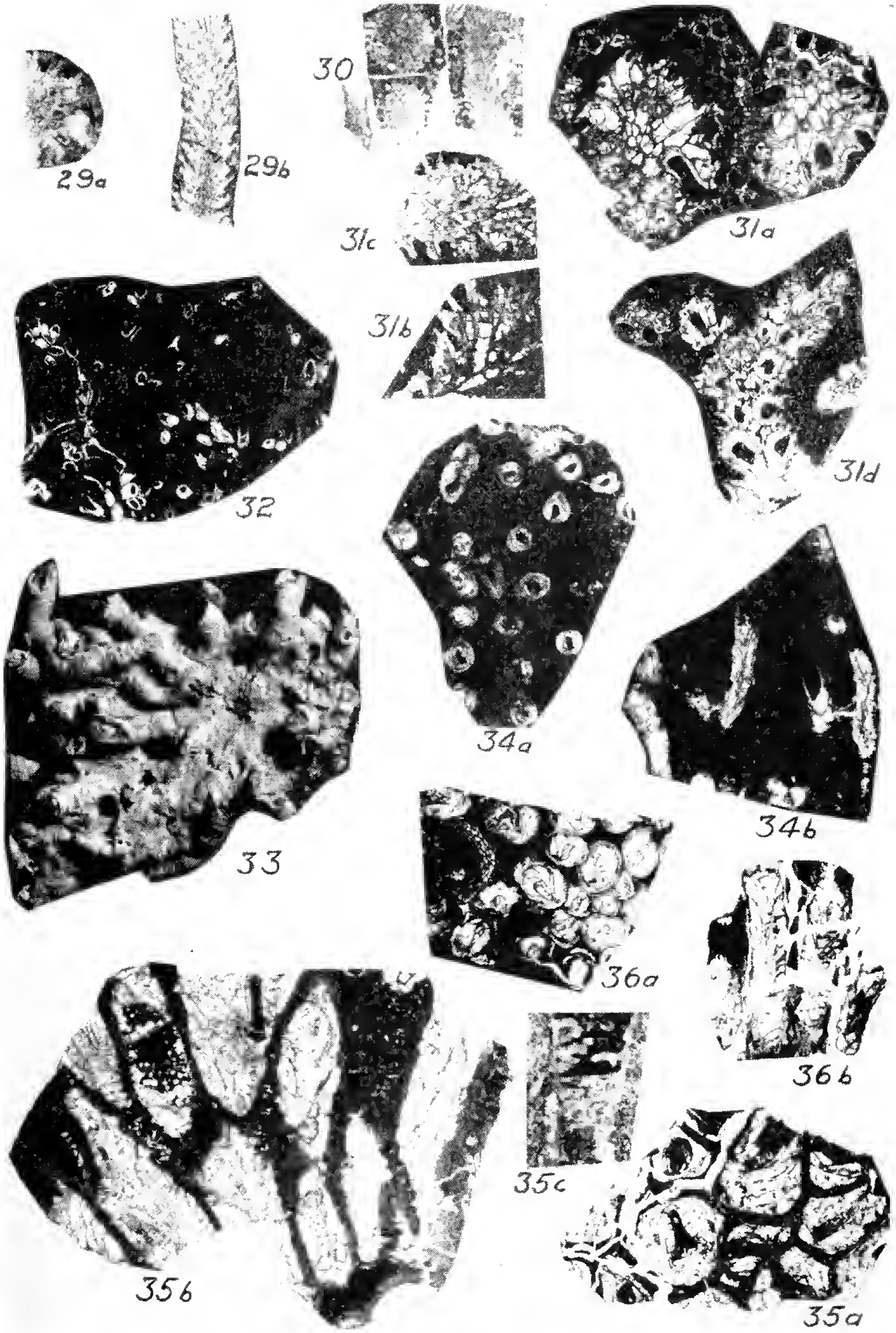
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Explanation of Plates

All figures ×2 diameters, except where otherwise stated.
For details of localities see p. 160.

Plate V

Couvinian Rugosa from the Buchan district, Victoria, and the Murrumbidgee district, New South Wales.

Fig. 1.—*Acanthophyllum aequiseptatum* Hill. Geol. Surv. Vic. 47765, Cave limestone of Loc. 97.

Fig. 2.—*Acanthophyllum* sp. Geol. Surv. Vic. 47713, from the *Spirifer* (= Cave) limestone of Loc. 82.

Fig. 3.—*Acanthophyllum* aff. *clermontense* (Etheridge). Geol. Surv. Vic. 48508 from the upper reef limestone in the Murrindal beds of Loc. 225; 3a, transverse section; 3b, median vertical section.

Fig. 4.—*Lyrielasma* aff. *floriforme* Hill. Geol. Surv. Vic. 48129 from the lower Murrindal beds of Loc. 167; 4a, oblique section; 4b, transverse section of young individuals.

Fig. 5.—*Xystriphyllum mitchelli* (Etheridge). Australian Mus. The horizontal section figured by Etheridge, 1892, pl. XI, fig. 10, probably cut from the lectotype, F.2418. The Cave, Murrumbidgee R., N.S.W.

Fig. 6.—*Xystriphyllum mitchelli* (Etheridge). Univ. Q'ld. Coll. F..10274, Rocky Camp, Buchan; upper Murrindal beds; 6a, transverse section; 6b, vertical section.

Fig. 7.—'*Campophyllum*' *recessum* Hill. Melb. Univ. Coll. 1968, slides 650 and 651. Spring Creek, Buchan; Cave limestone; 7a, transverse; 7b, median vertical section.

Fig. 8.—'*Campophyllum*' *recessum* Hill. Melb. Univ. Coll., slide 652, Spring Creek, Buchan; Cave limestone; oblique section.

Plate VI

Couvinian Rugosa and Tabulata from the Buchan district, Victoria.

Fig. 9.—*Disphyllum speleanum* sp. nov. Holotype, Geol. Surv. Vic. 47763B, Cave limestone, Buchan, Loc. 96; 9a, transverse section; 9b, vertical section.

Fig. 10.—*Disphyllum angulare* sp. nov. Holotype, Geol. Surv. Vic. 48079, lower Murrindal beds, Loc. 156; 10a, transverse section, adult stage; 10b, transverse section, young stage; 10c, median vertical section.

Fig. 11.—*Metriophyllum crisma* sp. nov. Holotype, Geol. Surv. Vic. 48901, Loc. 167; lower Murrindal beds; vertical section.

Fig. 12.—*Metriophyllum crisma* sp. nov. Geol. Surv. Vic. 47904, from Loc. 3; lower Murrindal beds; transverse sections of two individuals.

Fig. 13.—*Spongophyllum murale* sp. nov. Holotype, Univ. Q'ld. F.10272; locality uncertain, probably from Martin Cameron's quarry, lower Murrindal beds; 13a, transverse section; 13b, vertical section.

Fig. 14.—*Syringaxon radiatum* sp. nov. Holotype, Geol. Surv. Vic. 48113 (specimen reduced to thin section only), Loc. 167, lower Murrindal beds; transverse section.

Fig. 15.—*Syringaxon radiatum* sp. nov. Geol. Surv. Vic. 48910, vertical section. Same locality and horizon as Fig. 14.

Fig. 16.—*Alveolites stamineus* sp. nov. Holotype, Melb. Univ. 1954, slides 645 and 646, Murrindal; probably from Murrindal beds; 16a, transverse section; 16b, vertical and oblique sections.

Fig. 17.—*Alveolites* sp. Geol. Surv. Vic. 48507, upper reef limestone, upper Murrindal beds, Loc. 225.

Fig. 18.—*Alveolites* sp. Geol. Surv. Vic. 48492, upper reef limestone, upper Murrindal beds, Loc. 230.

Fig. 19.—'*Coenites*' *expansus* de Koninck. Geol. Surv. Vic. 48201, upper Murrindal beds, Loc. 177; 19a, b, sections through foliae; 19c, section tangential to folia.

Plate VII

Couvinian Tabulate Corals from the Buchan district, Victoria, and from Tamworth district, New South Wales.

Fig. 20.—*Favosites nitidus* Chapman. Geol. Surv. Vic. 48507A, upper reef limestone, upper Murrindal beds, Loc. 225; 20a, transverse section; 20b, vertical section.

Fig. 21.—*Favosites stelliformis* (Chapman). Paratype vertical section, W. N. Benson's Collection, Loomberah, N.S.W. Couvinian.

Fig. 22.—*Favosites stelliformis* (Chapman). Geol. Surv. Vic. 48541, Rocky Camp, Buchan, upper Murrindal beds; 22a, transverse section ×2; 22b, transverse section ×4; 22c, vertical section ×2; 22d, vertical section ×4. Note the spiral worm borings.

Fig. 23.—*Favosites bryani* Jones. Melb. Univ. 1962, slides 647 and 648, from Caves road quarry, Buchan, in Cave Limestone; 23a, transverse section; 23b, the same, ×4; 23c, vertical section; 23d, the same, ×4.

Fig. 24.—*Favosites* aff. *bryani* Jones. Geol. Surv. Vic. 47763, Cave Limestone, Loc. 96; 24a, transverse section; 24b, vertical section.

Plate VIII

Couvinian Tabulata from the Buchan district, Victoria.

Fig. 25.—*Favosites pluteus* sp.nov. Holotype, Geol. Surv. Vic. 48573, upper Murrindal beds, Rocky Camp; 25a, transverse and vertical sections, ×2; 25b, vertical section, ×4; 25c, transverse section; 25d, vertical section.

Fig. 26.—*Favosites pluteus* sp. nov. Melb. Univ. 1961, slide 649, upper Murrindal beds, Rocky Camp; 26a, vertical section; 26b, the same, ×4.

Fig. 27.—*Gephuropora duni* Etheridge. Geol. Surv. Vic. 48480, in lower Murrindal beds, 800 feet above the base of the Buchan series, in reef facies in valley south-east of Sandy's Homestead; 27a, transverse section; 27b, vertical section.

Fig. 28.—*Thamnopora alterivalis* (Chapman). Geol. Surv. Vic. 47708, Cave limestone, Loc. 79; 28a, b, c, thin sections.

Plate IX

Couvinian Tabulata from the Buchan district, Victoria.

Fig. 29.—*Thamnopora angulata* sp. nov. Holotype, Geol. Surv. Vic. 48507, upper reef limestone, upper Murrindal beds, Loc. 225; 29a, transverse section, ×4; 29b, vertical section.

Fig. 30.—*Thamnopora* aff. *angulata* sp. nov. Univ. Q'ld. F.10275, lower Murrindal beds, South Buchan limestone quarry.

Fig. 31.—*Thamnopora tumulosa* sp. nov. Holotype, Geol. Surv. Vic. 48324, lower Murrindal beds, Loc. 183; 31a, transverse section; 31b, vertical section; 31c, d, tangential sections.

Fig. 32.—*Aulopora* cf. *conglomerata* Goldfuss. Geol. Surv. Vic. 48698, lower Murrindal beds (20 ft. above the Cave limestone), Loc. 237; thin section.

Fig. 33.—*Syringopora flaccida,* sp. nov. Holotype, G.S.V. 48878, Cave Limestone, Loc. 255; natural size.

Fig. 34.—*Syringopora* sp. Geol. Surv. Vic. 48479, upper reef limestone, upper Murrindal beds, Loc. 222; 34a, transverse sections; 34b, vertical and tangential sections.

Fig. 35.—*Roemeria ocellata* sp. nov. Holotype, Melb. Univ. 1955, slides 642 and 643, from the upper Murrindal beds of Rocky Camp; 35a, transverse section; 35b, vertical section; 35c, part of 35b photographed in reflected light to show wrinklings in wall.

Fig. 36.—*Roemeria* sp. Geol. Surv. Vic. 47767 from the Cave Limestone of Loc. 97; 36a, transverse section; 36b, vertical section.

8

NOMENCLATURE OF CERTAIN TERTIARY SEDIMENTS NEAR MELBOURNE, VICTORIA

By Edmund D. Gill, B.A., B.D.*

[Read 8 December 1949]

Summary

In and around Melbourne are ferruginous sands and gravels popularly known as 'Red Beds', and for this lithological unit the formational name 'Sandringham Sands' is proposed. The bayside cliff at Red Bluff, Sandringham, is named as the type section. Palaeontologists have referred fossils from various parts of the formation to the Balcombian, Cheltenhamian, and Kalimnan Stages; the formation includes the type section of the Cheltenhamian Stage. To the north, these sands are covered by Newer Basalt, and to the south by fine grey aeolian sands.

Definition of Formation

Common in the geological literature of the Melbourne area are references to the 'Red Beds', so named by Hall, who nevertheless expressly stated that he was not thereby proposing a formational name (1909, p. 11). In any case, the name 'Red Beds' does not conform to the standard of stratigraphical nomenclature now being adopted (Glaessner *et al.* 1948), and so it is hereby proposed that the name 'Sandringham Sands' be employed.

The Sandringham Sands consist of a lithological unit readily recognized in the field, and are mapped herewith (Fig. 1).

The formation comprises clayey sands, sands, grit, and gravels stained and cemented to varying degrees by ferruginous infiltrations, hence the colour which suggested the name 'Red Beds'. The Sandringham Sands outcrop prominently along the north-eastern shore of Port Phillip Bay between Melbourne and Mordialloc, and in numerous road and rail cuttings and in quarries as far inland as Doncaster. The name is limited to the area mapped because more or less continuous sediments are present, so that there is no doubt about the deposits belonging to the one formation.

The type section for the Sandringham Sands is Red Bluff, Sandringham, where a shoreline cliff 80 feet high provides a greater exposure of stratigraphical thickness than anywhere else (Plate X). Selwyn's maps accompanying his earliest reports on the Melbourne area (1854, 1856) refer to this cliff, and Hart (1893, p. 157), Hall and Pritchard (1897, pp. 201-202), Daintree (1897, p. 3), and Hall (1909, p. 12) all refer to this conspicuous outcrop when describing or referring to the beds now called the Sandringham Sands. The base of the formation is not seen at Red Bluff, where an ironstone band occurs at sea level, but it is seen at a number of other places, the best known being the Royal Park railway cutting near Flemington. The Red Bluff cliff is capped with the younger fine grey aeolian sand which covers the whole terrain in this area.

On the Quarter Sheets of the Geological Survey of Victoria from 1858 to 1893 appear the names 'Flemington and Upper Brighton beds', 'Brighton beds' and

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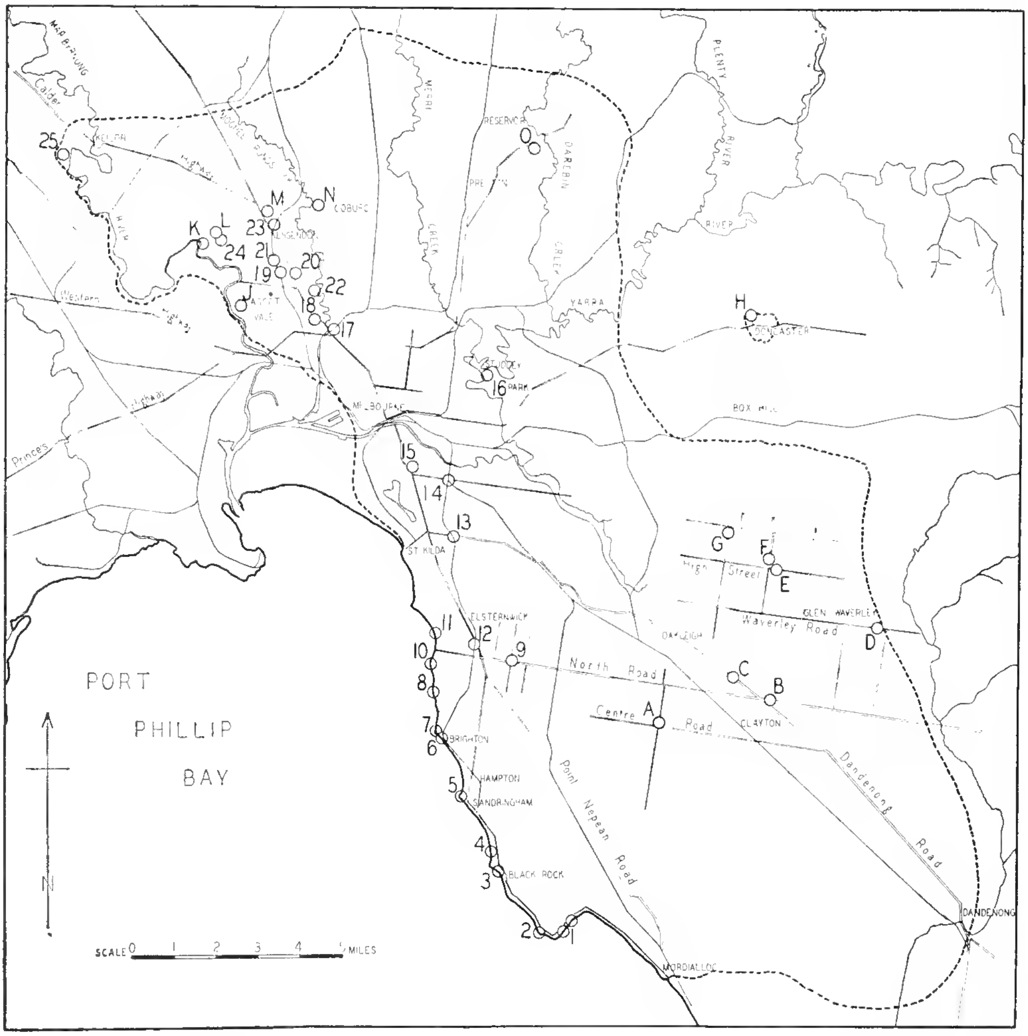

FIG. 1.—The dotted line shows the approximate limit of occurrence of the Sandringham Sands, as proved to exist below Newer Basalt and aeolian sands. The numbers 1-25 indicate the fossil localities as listed in the paper. Some of the main outcrops of the Sandringham Sands from which fossils have not been collected are indicated by letters as follows:

A. Near intersection of Centre Road and Warrigal Road.
B. Wellington Road, just east of Dandenong Road, Clayton.
C. Dandenong Road, near Park Street, Oakleigh.
D. Waverley Road, west of Lumm's Road, Glen Waverley.
E. High Street, east of Stevenson's Road, Mt. Waverley.
F. Stevenson's Road, north of High Street, Mt. Waverley.
G. Box Hill Road, just south of Boundary Road, Burwood.
H. Doncaster.
J. Angler's Parade, Ascot Vale.
K. Horseshoe Bend, Maribyrnong River, West Essendon.
L. Hoffman's Road, 200 yards north of Buckley Street, West Essendon.
M. Glen Street, Glenbervie.
N. Reynard's Road, West Coburg.
O. Plenty Road, North-East Preston.

Some of these localities have been mapped and described by Dr. D. E. Thomas (1947).

'Lower Brighton beds'. The names do not appear in the associated literature. For example, Selwyn, the Geological Surveyor of the Colony then, did not use it himself in his reports, or even in the section near Keilor published in the text of his 1856 report on the geology of the Port Phillip area. R. A. F. Murray (1887) wrote a book outlining the geology of Victoria when he was Geological Surveyor; it was published by the Government, but the above names were not used. As far as the writer can discover, the names have not appeared in press since 1893.

The Quarter Sheet covering Brighton was never published. It would appear that these names were used in a generalized manner, and not as strict formational names; it may be significant that the word 'beds' is always spelt with a lower case initial.

Early writers refer to the 'Brighton Cliff' (i.e., from Elwood to Mordialloc) with special mention of Red Bluff. The former was clearly the type section (as we would call it), and the latter the type locality. In those early days there was no name 'Sandringham', e.g., 'Brighton' and 'Moorabbin' are the only two names appearing in Selwyn's 1854 and 1856 maps of that area.

The type section and locality of the earlier writers are hereby adopted, and the name Sandringham Sands introduced for the beds underlying the grey sands, and overlying the limestone. The name 'Brighton Beds' could be conveniently retained in the term 'Brighton Group' to refer to all the beds outcropping in the cliff sections.

Literature

The Sandringham Sands have been widely referred to in literature, and so a selection is made relevant to the present purpose. Selwyn (1854, 1856) mapped 'horizontal stratified fossiliferous beds of red ferruginous mottled and chocolate coloured sand and sandstone commonly very soft and friable, often containing nodules and concretions of hard metallic-looking ironstone, and thick beds of very hard ferruginous quartz grit or fine conglomerate. Thickness exposed in the Brighton Cliffs 50′-80′.' Moreover, in the earlier paper, Selwyn also published in the text a section near Keilor showing:

Newer Basalt
Tertiary gravel (Sandringham Sands)
Palaeozoic Bedrock (Lowest).

When describing the rocks of the Brighton and Moorabbin districts, Hart (1893) distinguished the following:

Upper sand (loose, white)
Lower sand (compact, ferruginous)
Ironstone (lowest).

He held (erroneously) that there is an unconformity between the lower two units, and it is these which constitute the Sandringham Sands. Hall and Pritchard (1897, p. 190) pointed out that the supposed unconformity was cross-bedding. Notes on the lithology were given; 24 fossil localities (mostly in what are now called the Sandringham Sands) were listed, and palaeontological determinations provided. Hall (1890) and Grant (1901) described the exposures in the Royal Park railway cutting. Pritchard (1901) pointed out that different palaeontological horizons are present in the one formation.

It was Hall who in 1909 first used the name 'Red Beds' while setting out a systematic account for non-scientific readers of what is now called the Sandringham Sands. He drew a section from Picnic Point, Hampton, to Cotham Road, Kew, showing how these and other sediments rest on a sloping plain cut in the Silurian bedrock. Armitage (1910a) figured and described cross-bedded ferruginous sands on the Saltwater (Maribyrnong) River, and then later (1910b) described the deposits in greater detail, illustrating thin sections of the rocks.

Pritchard (1910) published an account of the geology of Melbourne, and showed outcrops of the Sandringham Sands in photographs of the Horseshore Bend on the Maribyrnong River (p. 78), Royal Park railway cutting (p. 86), Point Ormond (p. 152), maps showing this formation in the Studley Park (p. 132) and Botanical Gardens (p. 148) areas, and sections of the Maribyrnong River (p. 76) and the Royal Park cutting (p. 92). Hauser (1923) mapped at Studley Park sediments now referred to the Sandringham Sands, as also did Hills later (1940a), while Chapman (1923) claimed to determine a sea-urchin from there. Singleton (1923) likewise mapped the Royal Park area, and listed the fossils found in the Royal Park cutting.

Further north at Keilor are fossiliferous sands belonging to the new formation, and these were mapped and described by Miss Crespin (1926). Hills (1940b) figured (p. 274) sands at the West Essendon sand pits where they are covered with Newer Basalt and display strong current bedding in otherwise horizontal sediments. Hanks (1934) showed the extent of these sediments under Melbourne's northern suburbs.

Singleton (1941), in his account of the Tertiary geology of Australia, selected part of the exposure of the Sandringham Sands at Beaumaris (Pl. 2, fig. 2) as the type locality for a new stage which he termed the Cheltenhamian, and to which he ascribed an Upper Miocene age. In 1944 Mrs. Whincup published an account of the superficial sands which in the Melbourne-Frankston area overlie the Sandringham Sands.

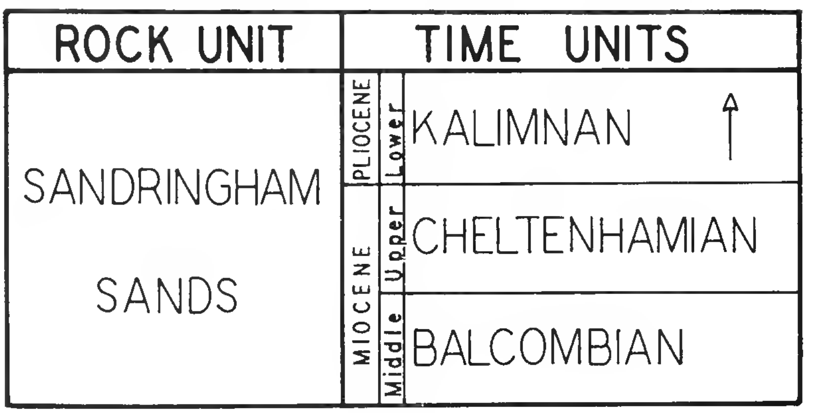

Fig. 2

Age of the Formation

Although the Sandringham Sands are a lithological unit conforming with the requirements for the definition of a formation, these sediments were laid down over a considerable period of time, as is represented diagrammatically in Fig. 2. The Stage names and the ages attributed to them are after Singleton (1941).

Fossiliferous beds at the base of the formation at Royal Park have been referred to the Balcombian Stage. The Upper Beds at Royal Park and beds exposed at Beaumaris are of Cheltenhamian age. Fossil localities in intervening places have been referred to the Kalimnan Stage. The writer knows of no fossiliferous horizon at the top of any section, and so it is not known with accuracy how far up the time scale the formation extends, hence the arrow in the top right hand corner of Fig. 2.

Immediately under the Sandringham Sands at Keilor (Crespin 1926, Singleton 1941) are limestones of Batesfordian age, but no fossils of this or earlier time have been found in the Sandringham Sands. However, the fact that red sands at Greensborough occur under the Older Basalt and at Doncaster stand on the Nillumbik Peneplain (Jutson 1910, Gill 1949) indicates that they belong to the pre-Older Basalt cycle, which is generally regarded as Oligocene. It may prove that the more seaward deposits are re-distributed Oligocene sands.

The following fossil localities in the new formation have been, or are now, recorded:

1.	Beaumaris	Hall and Pritchard 1897, Singleton 1941
2.	Rickett's Point	Hall and Pritchard 1897, Singleton 1941
3.	Black Rock	Gill 1950
4.	Red Bluff, Sandringham	Hart 1893, Hall and Pritchard 1897
5.	Picnic Point, Hampton	Hall and Pritchard 1897
6.	South of Brighton Beach	Gill 1950
7.	Brighton Beach	Hall and Pritchard 1897
8.	Park Street, Brighton	*Ibid.*, Hart 1893
9.	North Road, Brighton	*Ibid.*
10.	Bay Street, Brighton	*Ibid.*
11.	Park Street, Elsternwick	*Ibid.*
12.	Asling Street, Elwood	*Ibid.*
13.	Dandenong Road, Windsor	*Ibid.*
14.	Near South Yarra railway station	*Ibid.*
15.	Domain road, South Yarra	*Ibid.*
16.	Studley Park (?)	Chapman 1923
17.	Royal Park railway cutting	Hall and Pritchard 1897, Pritchard 1910, Singleton 1941
18.	West of Royal Park ('Flemington')	Hall and Pritchard 1897
19.	South end Moonee Ponds railway station	Pritchard 1901
20.	Corner Mt. Alexander and Pascoe Vale Roads (= Moonee Ponds Town Hall)	Armitage 1910b
21.	Corner Ardmillan Road and Taylor Street, Essendon	Armitage 1910b
22.	Brunswick Road, Moonee Ponds	Hall and Pritchard 1897, Pritchard 1910
23.	Near Essendon railway station	Hanks 1934
24.	West Essendon	Armitage 1910b
25.	Green Gully, Keilor	Officer 1893, Hall and Pritchard 1897, Crespin 1926

Facies

The presence in places of coarse gravels, the poor sorting of the sediments as a whole, and the frequency of strong cross-bedding indicate a shore line deposit. They constitute a contrast with the clays, marls, and limestones which preceded them. In the large sand pit in Hoffman's Road, West Essendon, the sands and gravels are horizontal on the whole, but dips ranging up to 23° persist for distances up to 20 yards and to a stratigraphical depth of 10 feet. The finding of freshwater spicules and leaves (Hanks 1934, pp. 145, 148; Crespin 1926, p. 107) wood (Hart 1893; Crespin 1926, p. 106), and a freshwater shell (Crespin 1926) fits the interpretation of the Sandringham Sands as estuarine and near-shore in facies. Most of the fossils are marine, but they include shallow water forms like *Haliotis*, and the intertidal form *Patelloida*.

Fossils are common in the Sandringham Sands in certain limited horizons and localities, but taken as a unit the formation is not a very fossiliferous one. More often than not the fossils are found in pockets, which indicates that they were swept together into hollows in the sea-floor by currents, then covered by other sediments and so preserved. In other words, these fossil localities are thanatocoenoses and not biocoenoses.

Generalizing, it may be said that the formation possesses a smaller percentage of silica and a greater percentage of clay as one crosses it from the inland edge towards the sea, suggesting a normal gradation in facies. Some of the clays found to the south of the Sandringham Sands may well prove to be a formation contemporaneous at least in part with the former.

In most places the Sandringham Sands are covered with younger rocks, and so the map (Fig. 1) is largely a list of localities. The overlying deposits consist chiefly of Newer Basalts in the more inland areas (see the Mines Dapartment Geological Map of Melbourne and Suburbs), and of aeolian sands in the bayside suburbs (Whincup 1944). The aeolian sands are probably derived from the Sandringham Sands, but are lithologically quite distinct.

Acknowledgment

I am indebted to Professor E. S. Hills and Dr. C. Teichert for discussing with me the definition of this new formation.

Figures 1-2 were drawn by Mr. J. J. Jenkin, of the National Museum, under the direction of the author.

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Description of Plate X

Fig. 1.—View at the top of the cliff at Red Bluff, looking northwards. The wind has swept the fine grey sands away at the cliff edge, exposing the Sandringham Sands formation. Note the 'bad lands' guttering already established on the wind-swept surface.

Fig. 2.—Red Bluff, Sandringham (type section for the Sandringham Sands formation), looking south. Note the resistant ironstone band at the base, and the 'bad lands' type of weathering which is characteristic of these sands. On top of the Sandringham Sands are the fine grey aeolian sands.

9

A SOIL SURVEY OF THE SHIRE OF WHITTLESEA, VICTORIA

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[Read 8 December 1949]

Summary

A survey has been made of the soils of the Shire of Whittlesea, to provide a background for a study of farming and living conditions in the district by the School of Agriculture, University of Melbourne.

The climate, physiography, geology, vegetation and soils of the district are described, and the soil types are defined. Their distribution is shown in a general map and in two detailed maps of typical areas.

The phosphorus status of the district soils, the difficulty of establishing subterranean clover on some soil types, and the problem of soil depletion are discussed.

Contents

Introduction

The Shire of Whittlesea is a rural area of some 215 square miles to the north of Melbourne, extending from twelve to thirty miles from the centre of the city, from the limit of the outer suburbs to the top of the Great Dividing Range. (Fig. 1.)

The population of the Shire is about 3,000. Most of the working population is engaged in farming, though the Shire is increasingly taking on the character of an outer suburb and many workers go to Melbourne daily; minor occupations include timber-getting and water supply (two of the city's reservoirs are in the area). The largest township is Whittlesea, with 300 people, and the Shire offices are in the township of Epping. There are half a dozen lesser centres, and there is still a slight concentration of settlement in former closer settlement areas such as Eden Park.

The earliest description of the district occurs in 1836; by 1840 most of the best land had been alienated; and by 1854 two-thirds of the present occupied area was in private hands. A demand for flour, dairy produce, and meat arose from the rapid growth of Melbourne, and after 1865 the hilly country east of the Plenty River was cleared for orcharding. The district's nearness to Melbourne has always

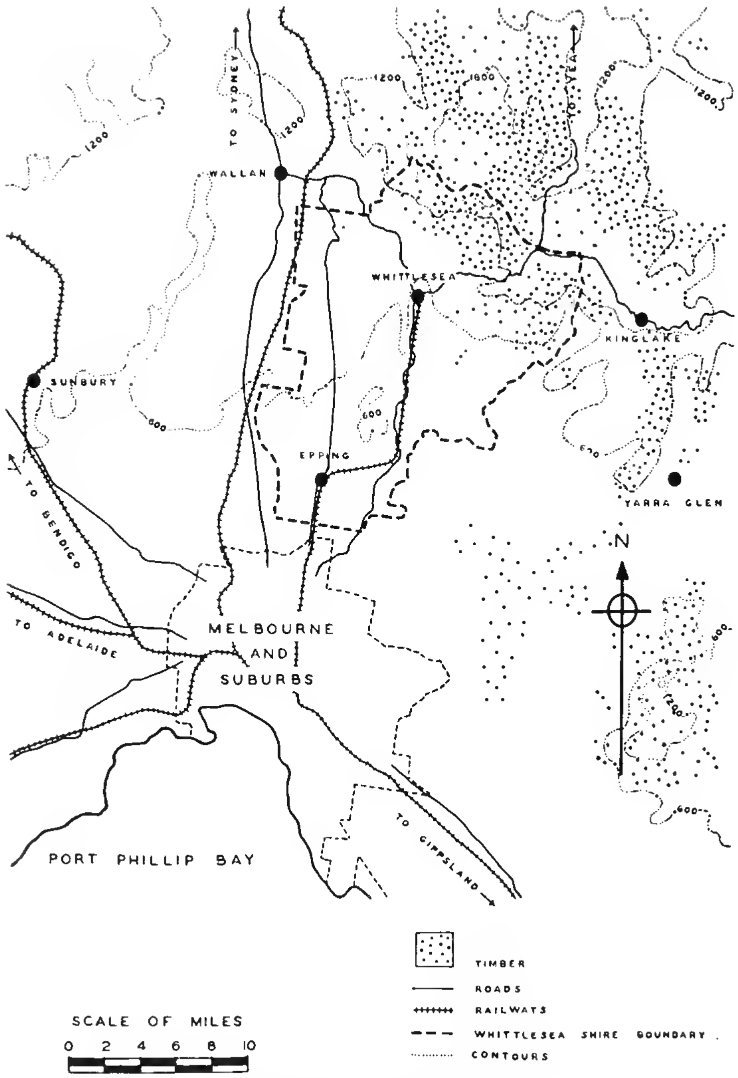

Fig. 1.—Locality Plan for the Shire of Whittlesea, showing also the extent of forested country.

made it a food and fodder producing area for the city, but its market has been threatened or lost from time to time by the extension of transport facilities to areas of more favourable soils and climate. Wheatgrowing in the Shire declined when the railway reached northern Victoria in 1860, butter and dairy production with the opening of western Victoria and Gippsland as dairying land. By 1915 the order of importance of the main industries was, firstly, dairying for whole milk production, then sheep and cattle raising, then the growing of oaten hay for the city's horses, and lastly orcharding. Since motor transport superseded horse transport in the 1920's, hay-growing has become quite unimportant, and there has been a great

increase in dairying, particularly in the depression years 1929-36. Lately, the whole milk market has been threatened by competition from milk brought long distances by road.

In 1946 a survey of land use, farm management, and living conditions in the Shire of Whittlesea was made for the School of Agriculture, University of Melbourne (1). The soil survey now described was designed to serve as a background for this work, which gives a complete account of the matters mentioned in this introduction.

Climate

Average annual rainfall figures for three stations in the Shire are as follows:

Epping	24.26 inches
Yan Yean	25.57 ,,
Toorourrong Reservoir	31.23 ,,

The annual rainfall increases with altitude from the south-west to the north-east of the area.

The mean monthly distribution of rainfall is irregular, and in fact the district suffers an annual 'drought' in summer and early autumn, from early December to late March, and very wet weather from early May to late October. From the records and weather observers' reports, the summer-early autumn drought may be expected to be fairly severe once every five or six years, but half the summers are not difficult at all, and one summer in six is highly favourable for grazing stock and growing summer crops.

The nearest temperature-recording station is at Watsonia, 1½ miles to the south-east of the Shire. This station's mean temperatures, between 47° F. and 49° F. for June, July and August, account for the very slow winter growth of pasture plants and crops, but a favourable late summer and autumn can mitigate these low winter temperatures. (Rainfall and temperature records supplied by Commonwealth Meteorological Bureau.)

Physiography

The physiography of the Shire is shown by the contour map (Fig. 2), which indicates the contrast between the mountains in the north and the plains in the south.

The northern boundary of the Shire is the crest of the Great Dividing Range, and near it lie some 50 square miles of most rugged country, of which the most notable features are Mount Disappointment, Mount Sugarloaf, Howat's Lookout and the Kinglake Plateau, and the valleys of the Plenty's tributaries (some of which supply the Toorourrong Reservoir) and the Running Creek gorge.

From the main range the foothills run south in two spur systems, with the broad valley of the Plenty dividing them. To the west are the hills round Eden Park, with a long narrow spur running south to She Oak Hill; to the east are the hills beyond the Yan Yean Reservoir, extending far past Arthur's Creek, the Shire boundary.

To the west and south of the foothills are the plains, their eastern limit the Plenty Gorge, their only interruption the Morang Hills, Summer Hill and some minor rises, and the courses of the Darebin and Merri Creeks.

The main drainage lines of the agricultural area are thus Merri Creek; Darebin Creek; the Plenty River and its tributaries, chiefly Bruce's, Crystal, and Scrubby Creeks, and Barber's Creek; Arthur's Creek and its tributaries, chiefly Deep Creek and Running Creek.

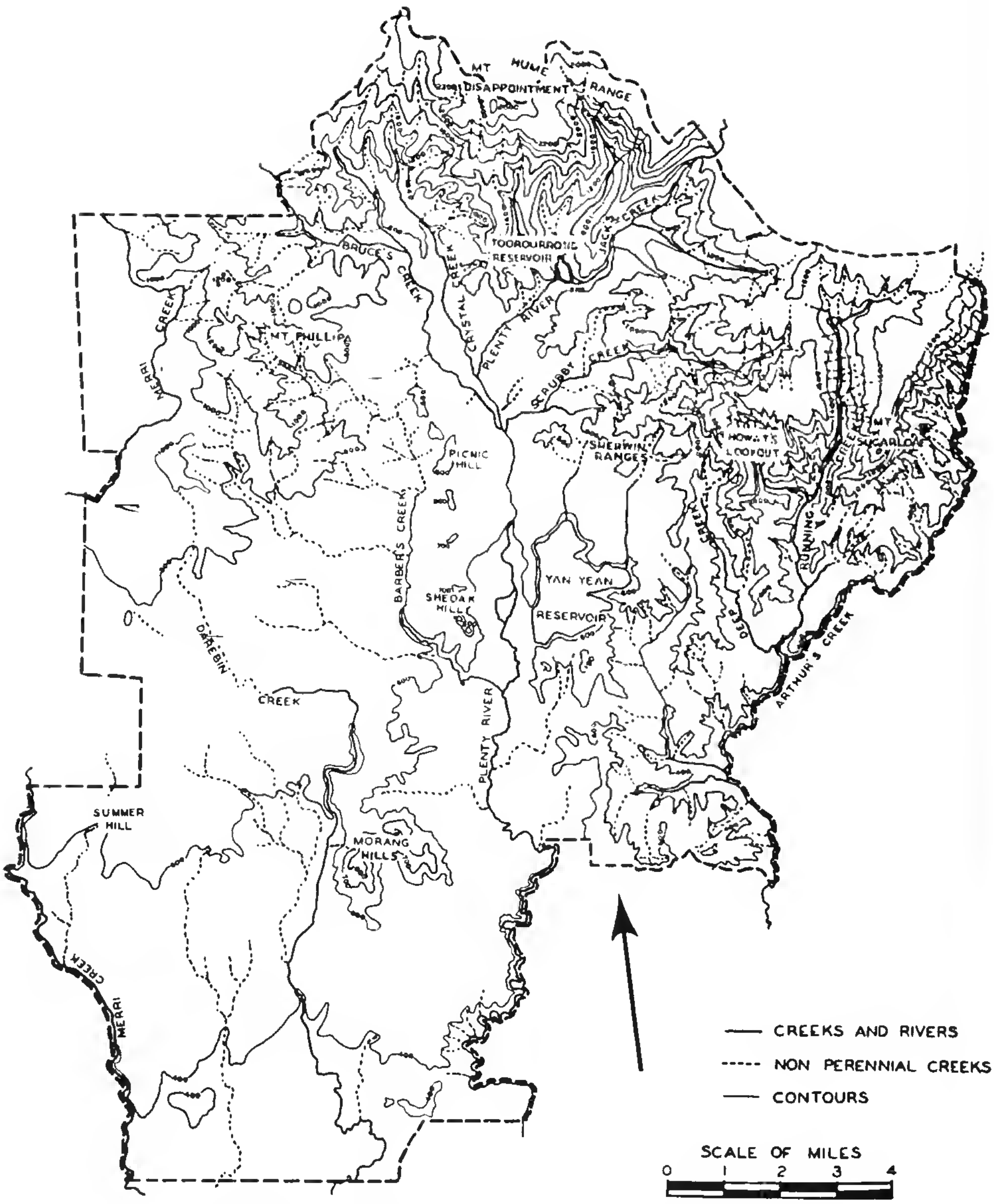

FIG. 2.—Map of the Shire of Whittlesea, showing physical features.

Geology

The Shire of Whittlesea is covered by quarter sheets of the Geological Survey of Victoria (2), and the soil map of the present survey (Fig. 3) is closely related to this geological reconnaissance map. Briefly, the north-eastern half of the Shire is mostly Silurian sediments, and the south-western half mostly Newer Basalt.

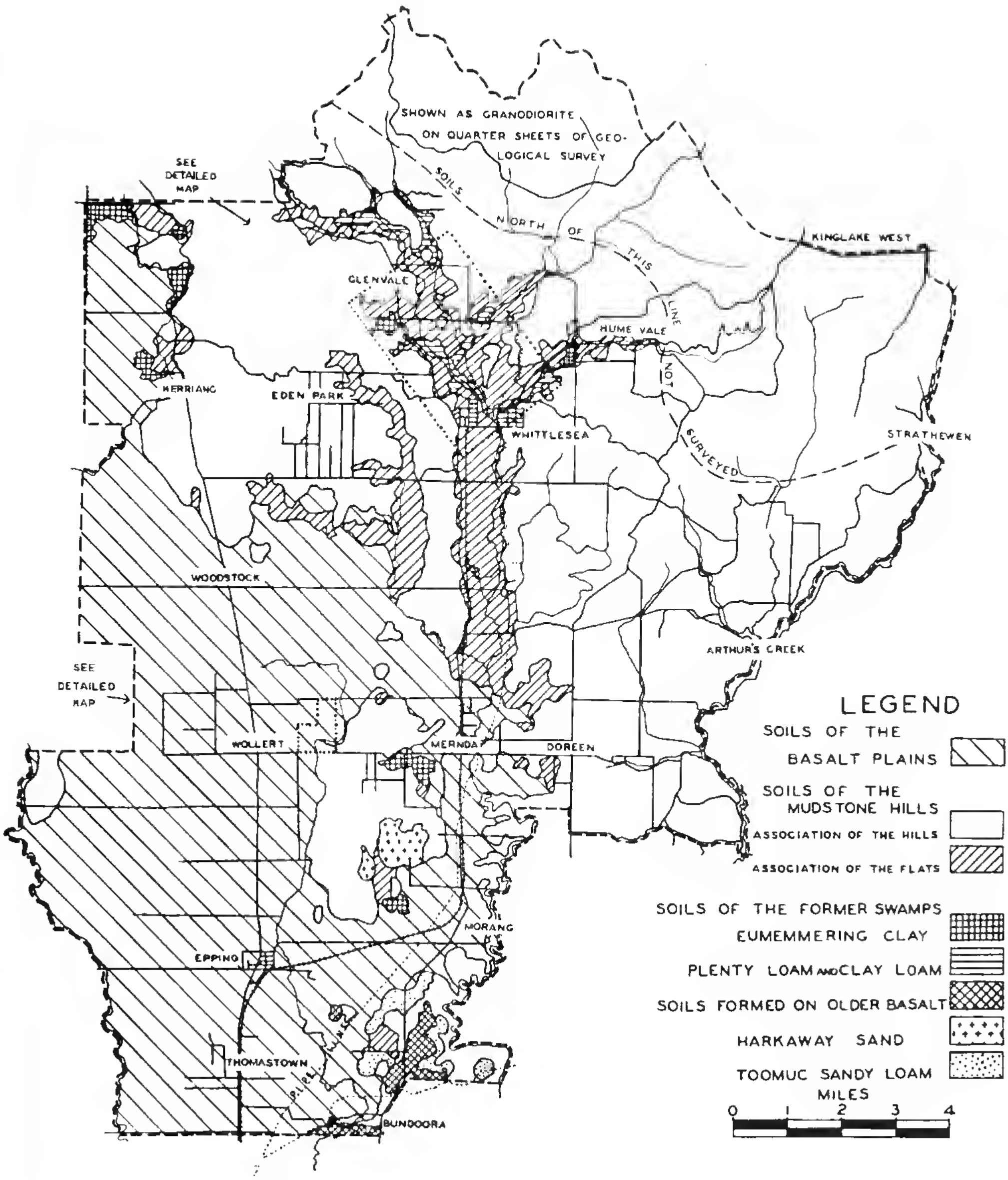

Fig. 3.—Soil Map of the Shire of Whittlesea, showing also place names.

There are also occurrences of Devonian granodiorite, Older Basalt, and Tertiary sediments.

The oldest rocks in the area are the Silurian sandstones, mudstones and shales, folded as follows (R. B. Withers, priv. comm.; 3):

(a) the Templestowe anticline, in the general direction of Arthur's Creek and east of it;

(b) the Whittlesea anticline, parallel to the Plenty River and then to Bruce's Creek, but slightly west of them;
(c) between (a) and (b), a very gentle synclinal fold in the north, towards Mount Sugarloaf, and many minor folds in the south, round Doreen;
(d) west of Eden Park, and separated from (b) by a strike fault, the Merriang syncline.

These Silurian rocks were intruded by granodiorite in Devonian times in two localities, the Morang Hills and the Hume Ranges, both now standing as monadnocks above the surrounding country. The Morang Hills have an eastern ridge of granodiorite fringed by metamorphosed sediments, and a western ridge capped by dense hornfels over granodiorite, which shows as a minor outcrop only (4).

The Hume Ranges are a much more extensive occurrence and are a remnant of a Cretaceous peneplain. The Kinglake Plateau represents later local peneplanation of softer rocks (Silurian sedimentary) around the resistant granodiorite. Even before the Older Basalt flows, this area was a divide, Mount Sugarloaf representing its steep southern escarpment, from which the divide has since migrated northwards owing to the steep gradient of the streams flowing south (5).

Basalt occurring as residuals in the south-eastern part of the Shire is similar to the Older Basalts of Greensborough and Kangaroo Ground, which have been assigned to the Oligocene or Lower Miocene period (6). Jutson has suggested that they may be of Pliocene age, an Intermediate Basalt (7), and the quarter sheets of the Geological Survey even show Mount Cooper as Newer Basalt (2), but for the purposes of this survey these basalt residuals will be referred to as Older Basalt.

Depression after the Older Basalt eruptions, and incursion of the sea in the present Melbourne area, caused the streams to form flood plain deposits, the relics of which are seen here as Tertiary gravels, grits and sands in the same area as the Older Basalt occurs (5).

Following a general Pliocene uplift, a mature topography had been developed by the time the Newer Basalt erupted, in the Middle Pliocene period or later. This basalt came from the north and west, and there are also centres of eruption in the Shire itself, near Donnybrook and south-east of Beveridge. It obliterated the drainage system over half the Shire, and blocked the Plenty River and many of its present tributaries, so that a new drainage system was developed in the west, and Barber's Creek and the Plenty River changed their courses. Before the basalt flow, Barber's Creek joined the present Darebin Creek valley north of the Morang Hills, and the Plenty joined the Darebin south of them, but the basalt diverted Barber's Creek into the Plenty, and the Plenty in turn into a young valley leading to Templestowe. Above the basalt blockage the river laid down the Whittlesea and Yan Yean flats, and the other dammed tributaries formed similar minor flats; along the basalt boundary and below it the river cut a winding gorge (8).

The present irregular surface of the Newer Basalt country is part of the solidified surface of the original basalt sheet, the stony rises and stony plains having been the basalt surface, and the depressions having been alluviated (9). The depressions are probably due to collapse of the solid crust of a basaltic sheet from the withdrawal of molten basalt from beneath. Possible causes of stony rise formation are:

(a) lateral pressure on the solid crust of the lava sheet;
(b) a lava's upthrust of its crust against irregularities of the buried surface;

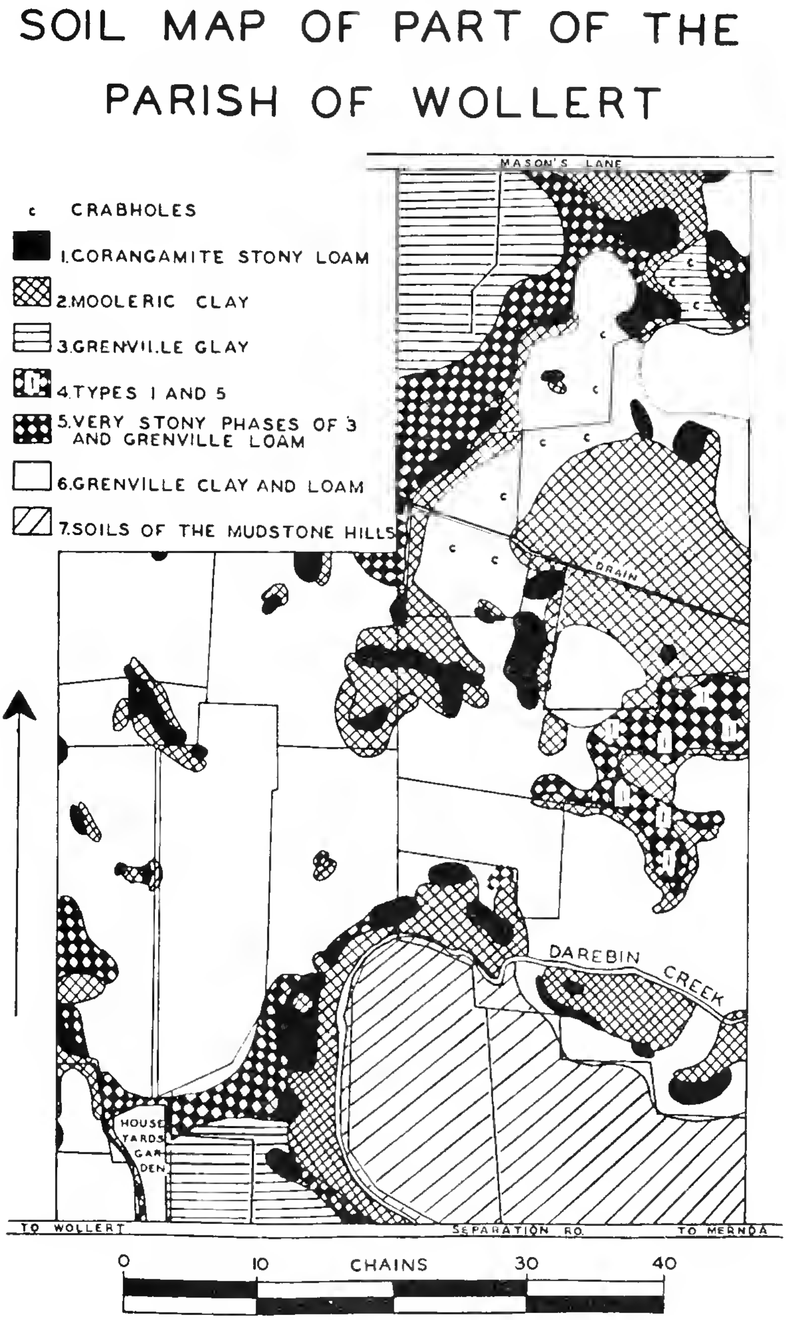

FIG. 4.—Detailed Soil Map of part of the Basalt Plains.

(c) holding up of a solid crust by a buried irregularity while the molten lava around flows out and lets its unsupported crust collapse;
(d) small fissure eruptions, marked by the present stony rises.

Vegetation

Areas still forested are shown in Fig. 1. These forests are most valuable on the better soils of the Hume Ranges and of the Kinglake Plateau, where there is a well-grown mountain ash-messmate (*Eucalyptus regnans-E. obliqua*) association. On the poorer soils of these plateaux and on the ranges near them there is messmate with peppermint (*E. radiata*) and broad-leaf peppermint (*E. dives*).

On the lower ranges, near Bruce's Creek and west of Eden Park, the usual association is red stringybark (*E. macrorrhyncha*) with peppermint and some broad-leaf peppermint. In the Sherwin Ranges there is more long-leaf box (*E. elaeophora*) with the red stringybark and the occasional peppermint. Further south, towards Hurstbridge, the association is red stringybark-long-leaf box-red box (*E. polyanthemos*), a usual association elsewhere (10). Yellow box (*E. melliodora*) is found throughout the mudstone hills country, messmate appears in almost any of its gullies, and swamp gum (*E. ovata*) on many flats.

In the cleared country north and west of Whittlesea and south and east of the Yan Yean reservoir, candlebark (*E. rubida*) is scattered freely. East of the Yan Yean reservoir there are also several snow-gums (*E. pauciflora*).

The most widespread Eucalyptus species in the area is the red gum (*E. camaldulensis* syn. *rostrata*), which is the only tree of the savannah woodlands on the basalt plains (11). It also grows on the Yan Yean flats and on other minor flats in the mudstone hills, but not further east than Deep Creek. A dense regrowth occurs where ground cleared of red gum is closed to grazing.

The area is so long settled that no other evidence is available, but it is said that the flats above Whittlesea had a dense cover of dogwood and tea-tree (probably *Cassinia aculeata* and *Melaleuca ericifolia* or *Leptospermum lanigerum*).

Soils

The accompanying soil map of the Shire of Whittlesea (Fig. 3) shows the following groups of soils:

A. Soils of the Basalt Plains.
B. Soils of the Mudstone Hills.
 (i) Association of the Hills.
 (ii) Association of the Flats.
C. Soils of the Former Swamps.
D. Soils formed on Older Basalt, Granodiorite, or Tertiary Sands.

The soils of the Basalt Plains could not be mapped usefully as separate types on the Shire map, but an area of 330 acres has been shown in detail in Fig. 4 to indicate the occurrence and complexity of the types within the basalt plains catena. The diversity of types within this classification on the Shire map must be emphasized.

In a similar way the two associations of the soils of the Mudstone Hills have been mapped to cover a number of types and of their varieties, and details of the occurrence are shown for 5,000 acres, including the important Whittlesea flats, in Fig. 5.

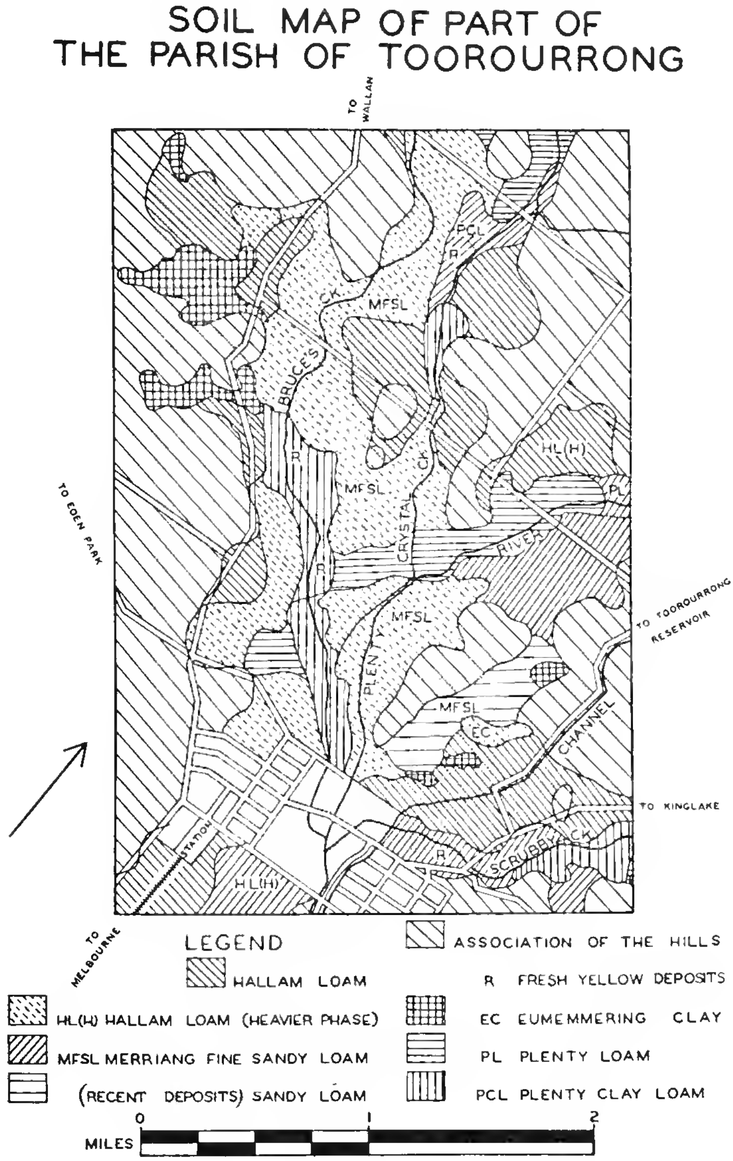

Fig. 5.—Detailed Soil Map of part of the Whittlesea Flats.

The other two groups have been shown by types in Fig. 3, the last group of unrelated minor soils being linked here merely for convenience.

Soils of the plateaux have not been mapped. Within the Shire, the plateau known as the Hume Range and much of the slopes leading up to it have been reserved for forestry and water supply; for this area only the granite-sedimentary boundary of the Geological Survey quarter sheet (2) has been shown. The soils of the Kinglake Plateau include deep red-brown or grey friable clay-loams and

clays (the famous Kinglake potato soils) as well as variants of Hallam and Yan Yean loams. All are formed on the same Silurian sandstones and mudstones, but the heavier soils are probably relics of a warmer and wetter climate.

The routine laboratory examination of the soil types defined was limited by the time available to a survey of their pH (by the quinhydrone electrode) and of their phosphorus status. The pH is given with the type descriptions, and phosphorus status is dealt with under sub-heading E.

A. Soils of the Basalt Plains

The soils of the Basalt plains in the Shire of Whittlesea are very similar to the 'soils of the plain' in the Mount Gellibrand area (12). The parent rock in both areas is a coarse-grained olivine-rich basalt, often vesicular, of the Newer Basalt flows; the basalt sheets have had similar topographies, the characteristic alternation

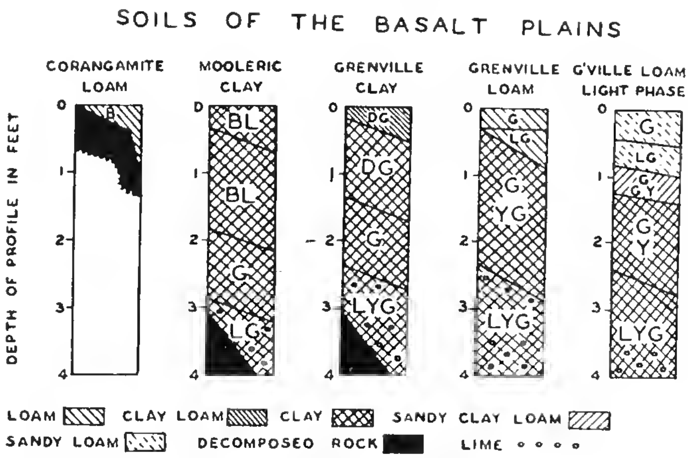

Fig. 6.—Diagrams of Profiles, Soils of the Basalt Plains.

of stony rise and depression, and the climates are alike enough to have produced the same range of types. The result is that most of the soil types of the Mount Gellibrand area are found here in a similar catena, Corangamite stony loam on the stony rises, Mooleric clay bordering the stony rises, Grenville clay and Grenville loam forming the slopes and plains beyond the influence of the stony rises, Grenville clay often running into crabhole and puff, and a type transitional between Corangamite stony loam and the Grenville series. The same catena has been observed in the Riddell district. In the Whittlesea Shire, however, the swampy phase of Grenville clay is limited to a few swamps only, and the 'pan and bank' complex of the depression is lacking, its place being taken by a very crabholey phase of Grenville clay or by a soil type like Mooleric clay. The only two basaltic hills in the Shire, one east of Donnybrook and one south-east of Beveridge, have soils that are classed with the plains types.

Descriptions of the main soils of the basalt plains as they occur in the Whittlesea Shire are as follows:

1. *Corangamite stony loam*

This is the soil of the typical stony rise, a brown loam up to four inches deep over the solid rocks or filling the crevices between them. It has a pH 5·9 and is

an immature soil, with no horizons differentiated, friable when wet and draining rapidly to be very dusty when dry, high in organic matter and very fertile. Occurrences range from a few square yards to four acres, but it is far too stony for cultivation.

2. *Mooleric clay*

The type profile is:

0-6	inches	Friable black clay	pH 6·3
6-24	,,	Black heavy clay	6·3
24-36	,,	Colour changing to light grey, heavy clay	
36-48	,,	Light grey heavy clay with light or medium amounts of soft or concretionary lime	7·8

Lime may occasionally come right to the surface, and basalt may be met at any depth below three feet. The surface is almost as uneven as crabholey ground, but there is no marked difference between the soils of rise and hollow, so the unevenness is best described as hummocky.

Mooleric clay occurs typically as patches or strips about a chain wide at the lower edges of stony rises, where it is enriched by wash and leaching from the Corangamite loam. Where similar enrichment has taken place by accumulated drainage, as in many depressions, Mooleric clay is formed away from stony rise influence. Such black hummocky flats are common along the wandering creeks of the basalt country, and in closed depressions up to 100 acres in extent, where the soil may be very deep.

3. *Grenville clay*

The profile of this type is:

0-3	inches	Dark grey clay	pH 6·3
3-18	,,	Dark grey heavy clay	6·7
18-30	,,	Grey heavy clay, traces of soft and nodular lime	7·3
30-48	,,	Light yellowish grey heavy clay, horizons with light to medium amounts of soft or nodular lime.	

The country basalt is found at any depth below three feet, and basalt 'floaters' up to a foot or two in diameter are common, their clearing from the surface giving the material for the stone fences characteristic of this countryside.

Grenville clay is one of the soils of the flat or gently sloping country between the stony rises. The presence of an occasional crabhole and puff, or sometimes a scattered group of them, is typical. Sometimes the occurrence of crabholes and puffs is so dense that no level soil can be found; this is mapped as—

3a. *Grenville clay, crabholey complex*

This complex has two members, crabhole puff and crabhole depression. The former is a heavy clay throughout the profile, grey at the surface and becoming lighter coloured and yellower with depth. The surface soil collapses to a nutty structure when dry, and soft or concretionary lime sometimes shows on the surface as well as at depth; pH for the first six inches, and for the next foot, is 6·5.

The depression has about six inches of dark grey silty or clay loam, pH 5·2, usually sticky when wet, and hard and cloddy when dry, overlying a rather dark grey heavy clay which becomes lighter in colour with depth. The horizons of puff, depression, and Grenville clay are the same below three feet, with a pH of about 7.

Puff and depression alternate. Each puff is a mound a yard or two wide, separated from other puffs by depressions of about the same width, the differences in level being six to twelve inches.

4. *Grenville loam*

With Grenville clay, Grenville loam forms the flat or sloping country away from the stony rises. The typical profile is:

0-4	inches	Grey silty loam	pH 5·4
4-8	,,	Lighter grey silty loam	5·4
8-18	,,	Mixed grey and yellow grey heavy clay	5·8
18-30	,,	Lighter coloured mixed grey and yellow-grey heavy clay	6·3
30-60	,,	Light yellowish grey heavy clay, up to light amounts of soft lime and some lime concretions	7·9

This profile overlies mixed clay and decomposing basalt, a transition to the country rock. The lighter coloured sub-surface soil may be absent, and about 1% of 'buckshot' (ironstone nodules) is usual throughout the profile.

4a. *Grenville loam, light phase*

This phase differs from the type in having deeper and somewhat lighter-textured A_1 and A_2 horizons, and a marked transition from them to the heavy clay below. Typically

0-5	inches	Grey fine sandy loam	pH 5·4
5-10	,,	Light grey fine sandy loam	5·7
10-15	,,	Mixed grey and yellow-grey fine sandy clay	6·1
15-24	,,	Mixed dark grey, grey and yellow heavy clay	6·1

and then as the type profile.

There are five hundred acres of this phase in the northern part of the Shire, forming plains behind the stony rises and slightly higher than them. Important centres of basalt eruption are so close that wind-blown additions to the parent material are suggested as a cause of the lightness of this basaltic soil (cf. distinction between Grenville clay and Grenville loam at Mount Gellibrand (12)).

5. *Very stony phases of Grenville loam and Grenville clay*

These phases, which correspond to 'Type 2' of the Mount Gellibrand survey, differ from the normal in having country basalt at or near the surface, as well as the typical boulders or floaters. Rock outcrop may form about a quarter of their surface. The soil between outcrops is two or three inches of grey loam or clay loam over dark grey clay, or a surface of friable self-mulching grey clay, solid rock coming at a depth of less than a foot. The crabholey phase of Grenville clay also occurs in the complex, usually with more puff than depression, and patches of Mooleric clay only a few square yards in extent are also frequent.

These very stony phases appear to be the result of soil formation under the restricted drainage of flat outcroppings of the original basalt sheet; under free drainage Corangamite stony loam would be formed. Hence on a shelf-like stony rise Corangamite stony loam is found at the front of the rise, and the very stony phases of Grenville loam and Grenville clay occupy the shelf behind the stony plains. Some of these patches have been cleared of stone, but it is usually considered impracticable to do so, and is certainly not economic.

B. Soils of the Mudstone Hills

Hills of Silurian mudstone like those of the Whittlesea Shire were covered by the soil survey of the country around Berwick (13). The types Hallam loam, Hallam loam (Silurian phase) (hereafter called shaley phase), and 'rugged Silurian country' described there form the greatest part of the Whittlesea country mapped as 'Association of the Hills', and Hallam loam is also the most extensive type of the Whittlesea 'Association of the Flats'.

Similar hills have also been studied near Warrandyte. (School of Agriculture, University of Melbourne, Students' Survey, 1946. Unpublished.)

The two associations are distinguished by their different topography arising from their different origins, the association of the hills including all types formed on mudstone or colluvium* at the foot of the hills, and the association of the flats those formed on alluvium deposited by streams whose drainage was blocked by the Newer Basalt flows. In practice the distinction is sharper than would appear from the separation of colluvium and alluvium.

The association of the hills is made up of

(1) Hallam loam.
(2) Hallam loam (shaley phase).
(3) Yan Yean loam, the 'rugged Silurian country' of the Berwick survey.
(4) An unnamed type.

*Alluvium has been defined as material deposited by streams; colluvium as material deposited by more general erosion.

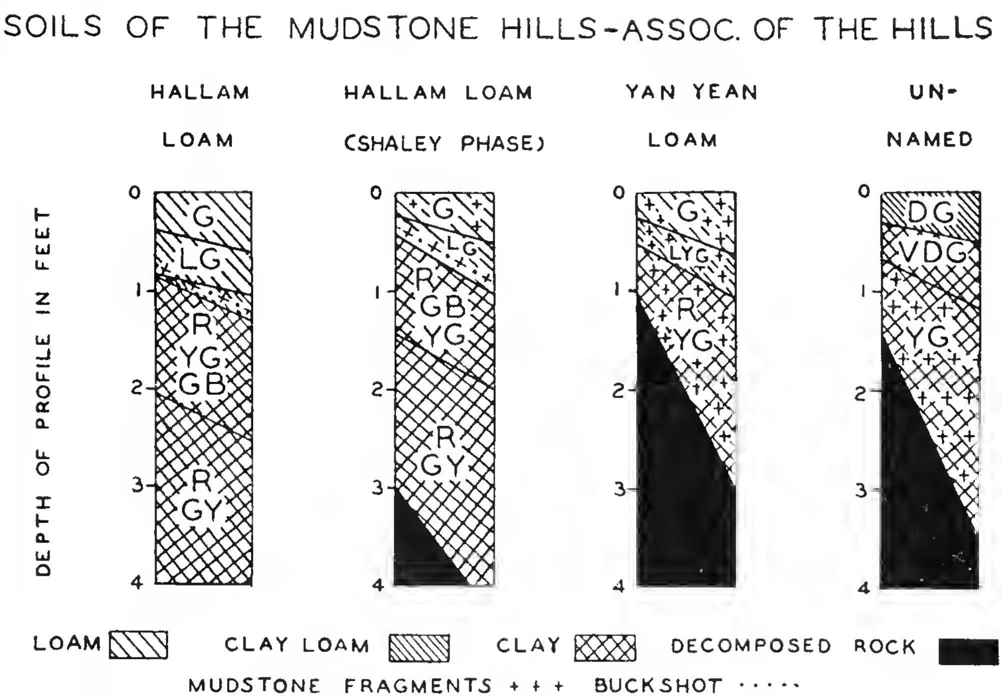

Fig. 7.—Diagrams of Profiles, Soils of the Mudstone Hills, Association of the Hills.

The association of the flats is made up of
Hallam loam.
(5) Hallam loam (heavy phase).
(6) Merriang fine sandy loam.
(7) Unnamed sandy loam, recent deposits.

The variation of fertility within the types of the association of the hills could not be covered by sampling on this survey, but an attempt to do so has been made by discussing geology and vegetation for this association in some detail.

Descriptions of the types are as follows:

1. *Hallam loam*

This type is common to both associations, covering the lowest and gentlest slopes in the mudstone hills country, and the higher level of the flats. The type description for the Whittlesea Shire is:

0-6	inches	Grey silty loam	pH 5·3
6-12	,,	Light grey silty loam	5·3
12-15	,,	Mixed light grey and yellow-grey clay loam	5·5
15-24	,,	Mixed grey-brown and yellow-grey with red heavy clay	5·9
24 on	,,	Greyish yellow with red heavy clay.	

The softened mudstone is met at about six feet and becomes harder with depth. The great change from the silty loam horizons to the heavy clay horizons is notable and is often emphasized by the absence of any clay loam transition layer. Typically on the slopes small amounts of iron-hardened mudstone fragments are found concentrated with buckshot just above the clay; on the flats mudstone fragments and buckshot are both absent. The colluvial soils are also usually deeper than the soil of the flats, probably having had surface soil as well as parent material added from higher up the slopes.

2. *Hallam loam (shaley phase)*

The shaley phase of Hallam loam has more mudstone fragments than the type, less depth to the mudstone below (less than 5 feet), and commonly less depth of soil. Mudstone fragments are found throughout the profile, and in moderate to heavy amounts with buckshot just above the clay. These differences are associated with the usual occurrence of the shaley phase on steeper slopes, causing a quicker erosion during soil formation and the addition of colluvium to the parent material of Hallam loam.

3. *Yan Yean loam*

Yan Yean loam is the soil derived from the shaley phase by even more erosion, occurring on the uppermost or most exposed slopes. The profile runs:

0-4	inches	Grey silty loam, slight amounts of mudstone fragments and buckshot	pH 5·3
4-8	,,	Light yellowish grey clay loam, moderate to heavy amounts of mudstone fragments, slight amounts of buckshot	5·3
8-18	,,	Yellow grey with red heavy clay, light amounts of mudstone fragments	5·3

and then soft mudstone, the depth varying from little more than a foot to about three feet.

4. *Unnamed type*

Small and unrelated occurrences of a darker and heavier type are found in the mudstone hills. The largest patch found was about 10 acres in extent, the parent material seemed to be the same Silurian mudstone as the Hallam and Yan Yean loams, and no hypothesis of the type's origin could be formed. Descriptions vary, but all are very different from the nearby Hallam or Yan Yean loam. A characteristic profile is:

0-4	inches	Dark grey clay loam	pH 5·7
4-12	,,	Very dark grey clay	5·7
12-24	,,	Yellowish grey heavy clay, light amounts of mudstone fragments	6·1
24-42	,,	Mixed yellow grey heavy clay, traces of mudstone fragments and then soft mudstone	6·6

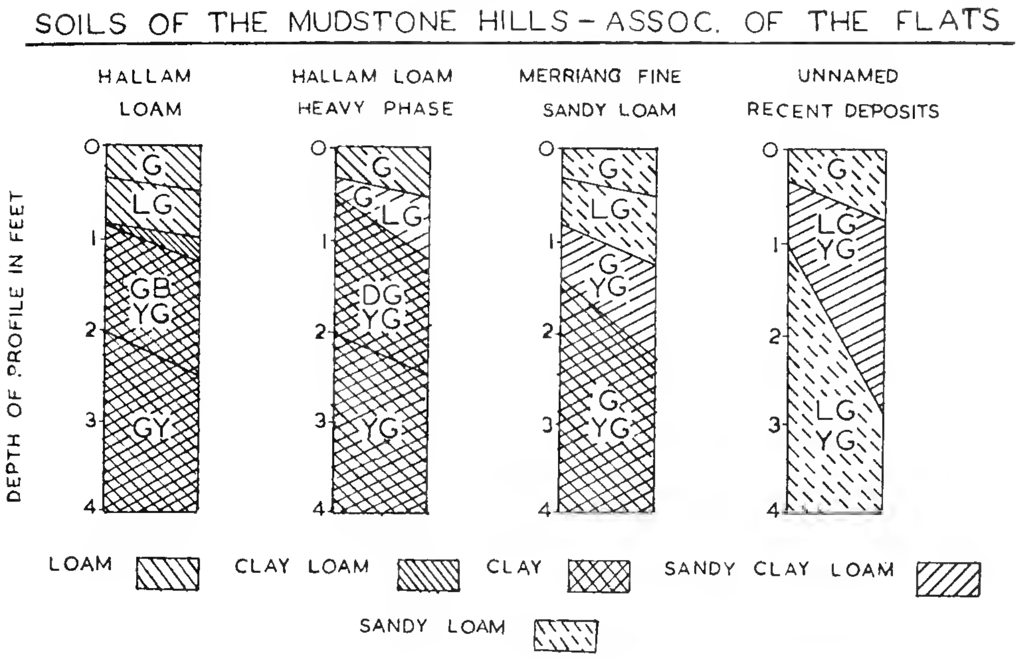

FIG. 8.—Diagrams of Profiles, Soils of the Mudstone Hills, Association of the Flats.

5. *Hallam loam (heavy phase)*

This heavy phase of Hallam loam usually occurs on slightly lower parts of the flats, mostly along drainage lines, but it may have a very even topography. The phase profile is:

0-6	inches	Grey loam	pH 5·1
6-15	,,	Grey, mixed with light grey and yellowish grey, sandy clay loam	5·3
15-24	,,	Dark grey, mixed with yellowish grey, heavy clay continuing as a rather yellower heavy clay	5·3

In some places on the flats north of Whittlesea the above profile may be gravelly throughout.

6. *Merriang fine sandy loam*

This type and the next are formed on material deposited at the foot of hills, often where a valley meets the Newer Basalt country. The typical Merriang fine sandy loam profile is:

0-6	inches	Grey fine sandy loam	pH 5·3
6-15	,,	Light grey fine sandy loam	5·4
15-24	,,	Mixed grey and yellow grey fine sandy clay	5·5
24-36	,,	Mixed grey and yellow heavy clay continuing for several more feet	6·4

This is an immature soil, with a lighter surface than Hallam loam and a more gradual transition to the heavy clay horizons.

7. *Unnamed sandy loam, recent deposits*

A more immature soil, an unnamed sandy loam, is formed on lighter and more recent deposits. The profile is:

0-8	inches	Grey sandy loam	pH 5·2
8-18	,,	Mixed light grey and yellow grey sandy clay loam, overlying horizons of loamy sand or sandy clay loam	5·6

Fine sand often dominates the sand fraction.

Recent erosion has caused extensive deposits of a yellow-grey fine sandy loam to fine sandy clay in watercourses and hollows. These become colonized by vegetation within a few months, and within eight years are carrying a fair cover of grass and, with added superphosphate, quite good subterranean clover. By this stage, they would be recognized as the unnamed sandy loam, and are therefore regarded as its parent material. In this survey these fresh deposits have been distinguished by yellowness in the surface.

C. Soils of the Former Swamps

There are three types of swamp origin only, characterized by high clay, high organic matter, or both, in their profile. These swamps may have been caused by local ponding in the mudstone country, or more commonly by the blocking of drainage by the Newer Basalt flows. One of the three types is very widespread here and has been described for the Berwick district (13), namely Eumemmering clay; the other two are more localized and have been named Plenty loam and Plenty clay loam.

1. *Eumemmering clay*

Eumemmering clay in the Whittlesea Shire occurs extensively in basins in the mudstone country, like its Berwick prototype, but it is also characteristic of depressions lying between the mudstone hills and the Newer Basalt. Mooleric clay, which may lie near it in the latter circumstances, differs from Eumemmering clay in forming hummocks, in having a darker colour, and in having a higher pH and lime within four feet. The profile for this Shire is:

0-3	inches	Very dark grey friable clay	pH 5·9
3-12	,,	Very dark grey heavy clay	6·1
12-24	,,	Dark grey heavy clay	6.3
24-36	,,	Grey, with a little yellow-grey, heavy clay	7·0

thereafter becoming lighter and yellower in colour but remaining heavy.

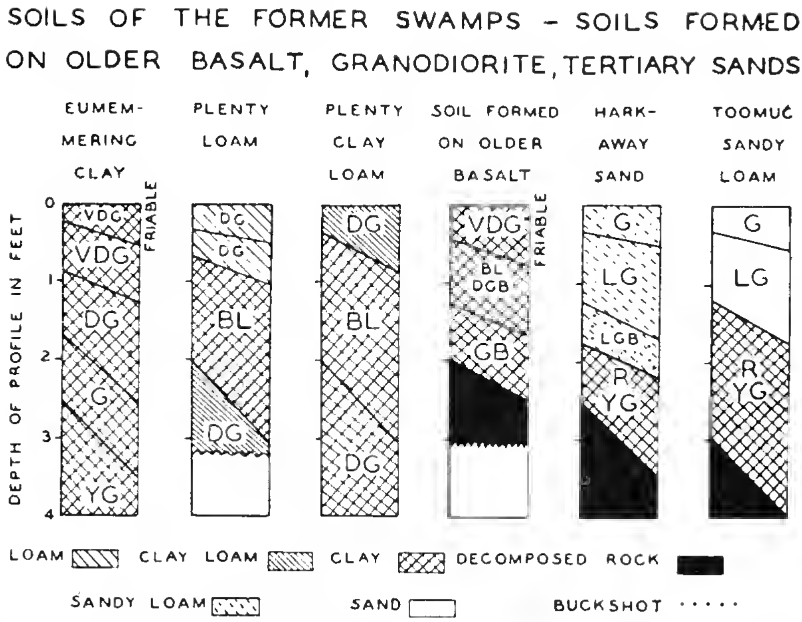

Fig. 9.—Diagrams of Profiles, Soils of the Former Swamps and Soils formed on Older Basalt, Granodiorite, and Tertiary Sands.

2. *Plenty series*

The two types of the Plenty series, Plenty loam and Plenty clay loam, are both high in organic matter, and are confined to the flats of the Plenty River and its tributaries above Whittlesea. Typical profiles are:

(a) Plenty loam

0-9 inches	Dark grey peaty loam	pH 4·9
9-12 „	Transition	
12-30 „	Black friable heavy clay	4.9

then a dark grey clay loam which was always water-logged when found on the survey.

(b) Plenty clay loam

0-9 inches	Dark grey friable clay loam	pH 5·2
9-30 „	Black heavy clay	5·3

continuing as a dark heavy clay for several feet deeper.

D. Soils formed on Older Basalt, Granodiorite, or Tertiary Sands

Two types of soil have been identified in this survey on Older Basalt parent material, but their naming has been deferred until more extensive occurrences of similar soils to the east of the Shire have been investigated. The soils formed on granodiorite in the Morang Hills area have been assigned to the type Harkaway sand, and those on Tertiary sands to the type Toomuc sandy loam, of the Berwick survey (13).

1. *Soils formed on Older Basalt*

Nearly all the area mapped under this heading is covered by a type like the 'black clay loam on basalt' of the Berwick survey. The profile is:

0-8	inches	Very dark grey friable clay	pH 5·8
8-18	,,	Black and dark grey-brown heavy clay	5·9
18-27	,,	Grey-brown, with black heavy clay, with light amounts of stone	6·4

the amount of stone increasing till solid rock is reached at about 30 inches. Floaters are common and depth to rock is variable.

The darkness of colour and heaviness of texture are notable, and the freedom from hummocks and occurrence on rounded hills are distinctive. Occasional mixed profiles were noticed, apparently due to a thin capping of basalt on Silurian mud stone country, and Hallam loam near Older Basalt soil is often shallower than usual.

Small patches of a brown soil, comparatively shallow and stony and confined to small rises, are also found on Older Basalt. A surface of six inches of brown friable clay overlies a red-brown heavy clay which becomes lighter coloured and very stony at 15 to 18 inches, just above solid rock.

2. *Harkaway sand*

The Harkaway sand of the Morang Hills is:

0-6	inches	Grey sandy loam	pH 5·6
6-18	,,	Light grey sandy loam	5·7
18-24	,,	Light grey-brown sandy loam, light amounts of ironstone concretions	5·9
24-30	,,	Yellow-grey and red heavy clay	6·1

which gives way at three feet or so to decomposing granite rock. The profile has much coarse sand in it throughout. The soil is deep, but granite boulders limit its useful extent, except on lower slopes where some wide areas free of boulders are found on the hill-wash.

3. *Toomuc sandy loam*

For the Whittlesea Shire, Toomuc sandy loam is described as

0-5	inches	Grey loamy sand	pH 5·2
5-9	,,	Lighter grey loamy sand	5·2
9-18	,,	Light grey loamy sand	5·6
18-27	,,	Yellow grey with red heavy clay, with appreciable sand,	6·0

becoming at three or four feet the brightly coloured sandy clay of the Tertiary sands. A high proportion of coarse sand is found throughout the profile.

Toomuc sandy loam is confined to the south-east part of the Shire, often adjoining Older Basalt soils because of their common association with residual hills.

E. Phosphorus Status of the Soils

Phosphorus status of the type samples is shown in Table 1. Total phosphorus was extracted by the tri-acid method of Groves (14), and readily available phosphorus by a method adopted in the Queensland Department of Agriculture and Stock*, namely, shaking 1 gm. of soil with 200 mls. of ·01 N sulphuric acid for six hours. Phosphorus in the extracts was determined colorimetrically, total phosphorus by the molybdenum blue method of Zinzadze (15), and readily available by the stannous chloride method of Truog and Meyer (16).

*C. R. von Stieglitz, priv. comm.

TABLE 1

Total Phosphorus and Readily Available Phosphorus of Type Samples

	Horizon (inches)	Soil Texture	Total P %	P Soluble in N/100 H_2SO_4 p.p.m.
Corangamite stony loam (v)	0-3	Loam	·089	44
Mooleric clay	0-6	Friable clay	·050	70
	6-25	Heavy clay	·034	15
Grenville clay	0-3	Clay	·031	24
	3-18	Heavy clay	·031	11
Grenville clay, crabholey phase, crabhole puff (v)	0-6	Heavy clay	·026	8
	6-16	Heavy clay	·024	4
Grenville clay, crabholey phase, crabhole depression (v)	0-6	Silty loam	·032	12
	6-16	Heavy clay	·031	7
Grenville loam	0-3	Silty loam	·027	23
	3-6	Silty loam	·026	14
	6-7	Silty loam	·019	
	7-18	Heavy clay	·027	
	18-27	Heavy clay	·026	
	30-42	Heavy clay	·026	
	42-48	Heavy clay	·024	
Grenville loam (another sample)	0-4	Loam	·036	14
	5-13	Heavy clay	·034	9
Grenville loam (light phase)	0-5	Fine sandy loam	·010	10
	5-10	Fine sandy loam	·009	4
Grenville clay, very stony phase	0-5	Friable clay	·053	156
	5-12	Heavy clay	·035	111
Hallam loam (on colluvium)	0-6	Silty loam	·035	91
	8-12	Silty loam	·009	11
Hallam loam (on alluvium)	0-6	Silty loam	·043	78
	6-10	Silty loam	·021	9
Hallam loam (shaley phase)	0-5	Silty loam	·038	23
	5-13	Silty loam	·029	10
Yan Yean loam	0-3	Silty loam	·058	35
	3-8	Clay loam	·017	7
Unnamed type	0-4	Clay loam	·057	30
	4-11	Clay	·011	14
Hallam loam (heavy phase)	0-6	Loam	·036	5
	6-15	Sandy clay loam	·020	3
Merriang fine sandy loam	0-7	Fine sandy loam	·026	12
	7-15	Fine sandy loam	·007	4
Unnamed sandy loam, recent deposits	0-8	Fine sandy loam	·041	6
	8-18	Fine sandy clay loam	·043	4
Eumemmering clay	0-3	Friable clay	·054	48
	3-12	Heavy clay	·022	6
Plenty loam	0-5	Peaty loam	·099	98
	5-9	Peaty loam	·106	89
Plenty clay loam	0-9	Clay loam	·105	52
	9-30	Heavy clay	·056	30
Soil on Older Basalt	0-8	Friable clay	·064	35
	8-18	Heavy clay	·042	30
Harkaway sand	0-6	Sandy loam	·020	8
	6-18	Sandy loam	·019	6
Toomuc sandy loam (v)	0-5	Sandy loam	·004	15
	5-9	Loamy sand	·004	7

(v) indicates soil never treated with fertilizer.

The most interesting of the total phosphorus figures are those for the Newer Basalt soils, since the phosphorus content ranges from .05% to ·01% (except for the immature Corangamite stony loam at ·09%) while the basalt rock itself has ·10%. For the profile of Grenville loam examined in detail the contrast between soil and parent rock is very striking; the average for the soil is ·026% P, and the rock has ·106%; material like soft discoloured basalt just above the parent rock has ·024%. There is no concentration of phosphorus in the ironstone nodules found throughout the profile, since these have too little phosphorus to determine.

An even greater loss of phosphorus during soil formation was found for the Mount Gellibrand basalts (12).

With the figures for readily available phosphorus, Table 2 shows quite a good relationship between an observed grading of soil quality and amount of phosphorus soluble in N/100 sulphuric acid, and the three discrepancies are explainable. Von Stieglitz (priv. comm.) mentioned 83% of 'positive' correlations in 130 samples of sugar-cane soils, with 40 p.p.m. as limiting.

TABLE 2

Relation between Observed Grading of Soil Quality and Phosphorus Soluble in N/100 Sulphuric Acid

Soil Quality	Very good	Good	Fair	Poor
	156	48	24	35[3]
P soluble in	98	44	23	15
N/100 H_2SO_4	91	35	23	12
p.p.m.	78	30	14	8
	70	10[1]	12	8
	52	6[2]		5

1 and 2 are light soils growing good subterranean clover; 3 is a soil which will not grow healthy subterranean clover and is probably calcium deficient.

Land Use

A. Grazing and Pasture Improvement

Utilization of pasture is the most important activity in the Whittlesea Shire, and pasture improvement is widespread. At present the improvement aimed at seldom goes beyond the perennial rye grass-subterranean clover (*Lolium perenne-Trifolium subterraneum*) combination. Of other sown grasses, cocksfoot (*Dactylis glomerata*) has had only moderate success, and phalaris (*Phalaris tuberosa*), although very successful in some instances, may not generally be preferred to rye grass. Of other sown legumes, white clover (*Trifolium perenne*) is not widespread now and usually disappears soon after seeding, although one would have expected types such as Mooleric clay, the Older Basalt soils, and the Plenty series to be able to hold it. Some clovers have been tried and discredited without an understanding of their function, e.g., red clover (*Trifolium pratense*) was expected to perennate. No particular strain of subterranean clover is favoured, and so-called natives such as spotted medic (*Medicago maculata*) and trefoil (*Medicago tribuloides*) are welcomed. In a few cases, lucerne (*Medicago sativa*) has grown well on Hallam loam in favoured situations.

Establishment of perennial rye grass-subterranean clover pastures appears practicable on all types except two, Yan Yean loam and Hallam loam (shaley phase). On these there have been many failures in establishment, the subterranean clover showing only as scattered and stunted plants, and the rye grass being weak for lack of clover support. Some of these failures have been corrected and some potential

failures have been prevented by lime dressings, of the order of $\frac{1}{4}$ ton of agricultural lime to the acre, and on small areas the spreading of dung has been effective.

Some plots of the Department of Agriculture, six miles north of the Shire and on a soil which appears to be Yan Yean loam, have given a remarkable response to lime. Establishment of subterranean clover is normal on plots receiving superphosphate and lime, or superphosphate, potassium and lime, the lime being applied at the rate of 10 cwt. to the acre. But the clover has failed under all other treatments—plots manured with superphosphate and other kinds of phosphate with and without potassium chloride, at several different rates of application, and cross-strips treated with zinc, copper, boron, magnesium, manganese and molybdenum .

During the soil survey a number of samples of the first three inches of soil were taken, and their pH determined (by the quinhydrone electrode) and tabulated against condition of clover. The results, in Table 3, show no correlation between growth of subterranean clover and pH for these soils.

TABLE 3

Soil pH and condition of Subterranean Clover

Treatment	Sown and top-dressed with superphosphate				Top-dressed with superphosphate, not sown			Natural pasture
Condition of sub. clover	Good	Fair Patch		Failure	Fair Patch		Failure	None present
pH of top three inches of soil.	5·5[1]	5·6	–	5·5	5·4	–	5·4	5·2
	5·6[2]	5·8[3]	–	5·3[3]	5·5	–	5·5	5·2[4]
	5·5[2]	5·5	–	5·3	5·4			5·2[5]
				5·7	5·3			
				5·4				

Adjoining samples are indicated by a link –

1. Treated with 5 cwt. of lime eight years ago.
2. Limed twenty years ago.
3. Treated with horse manure.
4. Mild sheet erosion.
5. Severe sheet erosion.

Further, a soil carrying good subterranean clover and one on which clover had failed were analyzed for water-soluble aluminium (by the aurintricarboxylic acid method of Roller (17)) and manganese (by the permanganate method of Willard and Greathouse (18)), since both these elements might become toxic at such pH values. No significant difference between good and bad was found, and the amounts extracted were well below toxic limits, namely 1·2 p.p.m. Al, while Mn was not determinable for good and bad clover soils. The problem therefore remains unsolved, but may be one of calcium deficiency, a view which is supported by further work by the Victorian Department of Agriculture since the soil survey was completed. (W. D. Andrew, priv. comm.)

The survey was not intensive enough to find more than a broad relation between problem and soil type. While the trouble can sometimes be related to sheet erosion on the two 'difficult' types, much of the land classed as Yan Yean loam and Hallam loam (shaley phase) has always been under timber or natural grass and yet has given a poor response to top-dressing. The native clovers have given little added growth, and subterranean clover has made as patchy progress as on long-cropped land where it has been sown down.

Of the area shown as 'Association of the Hills', about half is forest country, and most of the remainder is country on which subterranean clover establishment has been, or may be, difficult. However, it seems reasonably certain that lime in addition to the usual superphosphate dressings will give establishment.

On other soil types there is a good response to top-dressing with superphosphate alone; the native legumes are encouraged and subterranean clover is easily introduced. Toomuc sandy loam may be an exception, but the extent of attempted improvement on this type was too small to prove or disprove this. The only real difficulty is on the soils of the basalt plains, and is the physical difficulty of moving the top-dressing machinery over very stony ground. At least one owner of large areas of basalt plains finds that it pays to accept possible breakages of machinery and to top-dress natural pasture with introduced subterranean clover on the soils of the basalt plains.

B. Cereal Growing

Oats for hay, and to a less extent for grain, have been grown on all types, but those favoured are Yan Yean loam, Hallam loam (shaley phase), Hallam loam, Grenville clay, and Grenville loam, because of the quality of the hay produced. The average yield on these soils is about 30 cwt. of hay, and the Grenville series is rather remarkable in being able to produce such a yield year after year by means of a late harvest and late sowing, a six months' fallow, and manuring with 1 cwt. of superphosphate per acre every year. Richer types, such as Mooleric clay or the unnamed type of the association of the hills, usually produce rather too leafy a crop, and on the Older Basalt soil, for example, weed control is a problem.

A little wheat is grown, mostly on Hallam loam and the Grenville series; a little barley is grown on Hallam loam and Hallam loam (shaley phase); linseed has been grown on Hallam loam; and summer fodders such as maize and millet are grown in many small areas on all types.

C. Fruit and Vegetable Growing

Apples are grown on Hallam loam (shaley phase) and Yan Yean loam in the north-east part of the Shire, because of the higher rainfall, in the important apple-growing districts of Strathewen and Arthur's Creek and in orchards in the Deep Creek area and on the ranges towards Kinglake West.

Potatoes and peas grow well on the Plenty series, particularly Plenty loam. Tomatoes have done very well on the unnamed sandy loam on recent deposits along Arthur's Creek, with some irrigation.

D. Soil Depletion

It is hard to find good evidence of soil exhaustion by cropping in the Shire, despite a current impression to the contrary. Parish records for the last seventy years do show a slight decrease in average yield per acre of cereals in spite of increased areas of fallow and increased usage of superphosphate, but it was impossible to find particular instances of exhausted land. In one case examined, for example, where exhaustion was suspected, the true cause appeared to be poor cropping practice only.

On the other hand, the area sown down to mixed pastures has increased in that period, and although much former crop land has not been improved beyond letting it lie idle under wild grasses, there is another current impression that fertility of the Shire is increasing.

In this connection the survey of the phosphorus status in Table 1 is interesting, but it must be remembered that these figures are for the type samples, and do not represent a random selection to investigate depletion.

Evidence of soil exhaustion by erosion is abundant, and probably most easily seen in the areas of the unnamed sandy loam on recent deposits which is largely an erosion product, and of fresh yellow deposits which are solely due to erosion. Erosion is confined to the association of the hills except for gullying across the association of the flats and in one case across Grenville loam. In the association of the hills, all kinds of erosion may be seen, sheet, gullying, and the tunnelling recently described in the Dookie district (19). Much orchard country has suffered severely, and crop land may suffer badly in an exceptional rain, but the most consistent damage is seen on the poor wallaby grass (*Danthonia* spp.) pastures on Yan Yean loam and Hallam loam (shaley phase). These are the very types on which improvement of pastures is likely to prove difficult, not only because of the large areas involved and their steepness, but also because these two types are 'difficult' for subterranean clover establishment. This is the country dealt with in the Soil Conservation Board erosion control demonstration at Merriang, where contour furrowing on grassland and contour cultivation on cropland are shown.

Salt accumulation is also conveniently dealt with here. Many occurrences have been observed, and the findings of the Berwick survey (13) apply equally well to Whittlesea; cause and effect are the same in both cases, and the non-productive patches are so small comparatively to the properties where they are found that attempts to reclaim them have been regarded as uneconomic.

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Clark, A. M., M.Sc., Ph.D., Zoology Department, The University, Carlton, N.3	1940
Clark, G. Lindsay, M.C., B.Sc., M.M.E., c/o Gold Mines of Australia Ltd., P.O. Box 860K, Melbourne, C.1	1931
Colliver, F. S., Geology Department, University of Queensland, Brisbane, Queensland	1933
Coulson, A. L., D.Sc., D.I.C., F.G.S., 324 Cotham Road, Kew, E.4	1919
Cox, Leonard B., M.D., B.S., M.R.C.P., 719 Toorak Road, Malvern, S.E.4	1946
Davis, J. K., "Dundrennan," 492 St. Kilda Road, Melbourne, S.C.2	1920
Day, Arthur J., M.B., B.S., 227 Toorak Road, South Yarra, S.E.1	1946
Devine, John, M.S., F.R.C.S., 57 Collins Street, Melbourne, C.1	1945
Drummond, F. H., Ph.D., B.Sc., Zoology Department, The University, Carlton, N.3	1933
Edwards, A. B., D.Sc., Ph.D., D.I.C., Geology Department, The University, Carlton, N.3	1930
Esserman, N. A., B.Sc., A.Inst.P., National Standards Laboratory, University Grounds, Sydney, N.S.W.	1923
Fitts, Clive H., M.D., 14 Parliament Place, Melbourne, C.2	1945
Gepp, Sir Herbert, Cliveden Mansions, 192 Wellington Parade, East Melbourne, C.2	1926
Gill, Edmund, D., B.A., B.D., 26 Winifred Street, Essendon, W.5	1938
Gray, K. Washington, M.A., Ph.D., 90 William Street, Melbourne, C.1	1946
Grice, J. Hugh, "Highfield," Lilydale	1938
Grimwade, Sir Russell, Kt.B., C.B.E., B.Sc., 342 Flinders Lane, Melbourne, C.1	1912
Hartman, S., c/o The James Bell Machinery Co. Pty. Ltd., 200 King Street, Melbourne, C.1	1946
Hartung, Prof. E. J., D.Sc., Ph.D., The University, Carlton, N.3	1923
Hills, Prof. E. S., D.Sc., Ph.D., The University, Carlton, N.3	1928

Hordern, A., 242 Walsh Street, South Yarra, S.E.1 1940
Jack, R. Lockhart, B.E., D.Sc., F.G.S., 54 Clowes Street, South Yarra, S.E.1 1931
James, A. V. G., B.A., D.Sc., 23 Bayview Crescent, Black Rock, S.9 1917
Jutson, J. T., D.Sc., LL.B., 9 Ivanhoe Parade, Ivanhoe, N.21 1902
Kannaluik, W. G., D.Sc., Physics Department, The University, Carlton, N.3 1946
Kesteven, H. Leighton, D.Sc., M.D., Palmwoods, Queensland 1945
Kimpton, V. Y., 16 Lansell Road, Toorak, S.E.2 1946
Lang, P. S., B.Agr.Sc., Titanga, Lismore 1938
Leeper, Assoc. Prof. G. W., M. Sc., Chemistry Department, The University, Carlton, N.3 1931
Lewis, Essington C. H., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1945
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary Road, Burwood, E.13 1921
MacCallum, Prof. P., M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., The University, Carlton, N.3 1925
McPherson, Sir Clive, C.B.E., 216 Domain Road, South Yarra, S.E.1 1946
Manning, C. T., "Airlie," 452 St. Kilda Road, Melbourne, S.C.2 1950
Martin, Prof. L. H., Ph.D., F.Inst.P., The University, Carlton, N.3 1945
Medley, Sir John, Kt.B., M.A., The University, Carlton, N.3 1945
Miller, E. Studley, 396 Flinders Lane, Melbourne, C.1 1921
Miller, Leo F., "Moonga," Power Avenue, Malvern, S.E.4 1920
Millikan, C. R., M.Agr.Sc., Plant Research Laboratory, Swan Street, Burnley, E.1 .. 1941
Montgomery, J. N., c/o Australasian Petroleum Company, 37 Queen Street, Melbourne, C.1 1945
Moore, K. Byron, 11 Mona Place, South Yarra, S.E.1 1945
Morrison, P. Crosbie, M.Sc., Herald Office, 44-74 Flinders Street, Melbourne, C.1 .. 1938
Murdoch, Sir Keith, Albany Road, Toorak, S.E.2 1945
Murphy, H. D., Mornington 1950
Nicholas, George R., 48 Lansell Road, Toorak, S.E.2 1934
Olsen, C. O., B.A., Dip.Ed., 46 Clendon Road, Toorak, S.E.2 1945
Orr, R. Graeme, M.A., B.Ch., 9 Heyington Place, Toorak, S.E.2 1935
Patton, R. T., D.Sc., M.F. (Harv.), D.I.C., 13 Hartley Avenue, Caulfield, S.E.8 .. 1922
Pescott, R. T. M., M.Agr.Sc., F.R.E.S., National Museum, Russell Street, Melbourne, C.1 1944
Pitt, E. R., B.A., F.L.A., "Belmont," 146 Grey Street, East Melbourne, C.2 1946
Pittman, H. A. J., B.A., B.Agr.Sc. (Hons.), Dip.Ed., Plant Research Laboratory, Swan Street, Burnley, E.1 1942
Preston, H. E., 128 Glen Iris Road, Glen Iris, S.E.6 1949
Quayle, E. T., B.A., 27 Collins Street, Essendon, W.5 1920
Reid, J. S., 498 Punt Road, South Yarra, S.E.1 1920
Rivett, Sir David, K.C.M.G., M.A., D.Sc., 474 St. Kilda Road, Melbourne, S.C.2 .. 1911
Rogers, J. S., M.C., B.A., D.Sc., F.Inst.P., The University, Carlton, N.3 1924
Sayce, E. L., B.Sc., F.Inst.P., Defence Research Laboratories, Maribyrnong, W.3 .. 1924
Simpson, H. P., 36 Albion Road, Glen Iris, S.E.6 1948
Spicer, P. O., 6 Inverness Way, Balwyn, E.9 1946
Stokes, Dr. H. Lawrence, 417 St. Kilda Road, Melbourne, S.C.2 1945
Sullivan, W., 326 Exhibition Street, Melbourne, C.1 1943
Sunderland, Prof. S., D.Sc., M.B., B.S., The University, Carlton, N.3 1945
Tattam, C. M., Ph.D., D.Sc., Geology Department, The University, Carlton, N.3 .. 1945
Teichert, C., D.Sc., Geology Department, The University, Carlton, N.3 1945
Thomas, D. E., D.Sc., Mines Department, Melbourne, C.2 1929
Thomas, D. J., M.D., 81 Collins Street, Melbourne, C.1 1924
Tiegs, Prof. O. W., D.Sc., F.R.S., The University, Carlton, N.3 1925
Tulloch, N. M., B.Agr.Sc., Animal Health Laboratory, C.S.I.R.O., Flemington Road, Parkville, N.2 1950
Turner, Prof. J. S., M.A., Ph.D., M.Sc., The University, Carlton, N.3 1938
Vail, Col. L. E., E.D., 26 Chaucer Street, Canterbury, E.7 1939
Wadham, Prof. S. M., M.A., Agr.Dip., The University, Carlton, N.3 1932
Warren, H. N., Central Weather Bureau, Box 1289K, Melbourne, C.1 1946
Wettenhall, Dr. Roland R., "Aberfeldie," 357 Toorak Road, Toorak, S.E.2 1938
White, Dr. A. E. Rowden, 14 Parliament Place, Melbourne, C.2 1938
Wilcock, A. A., B.Sc., B.Ed., Geology Department, The University, Carlton, N.3 .. 1934
Willis, A. G., M.Sc., Zoology Department, The University, Carlton, N.3 1949
Withers, R. B., M.Sc., Dip.Ed., Food Preservation Research Laboratories, Private Bag, Homebush, N.S.W. 1926
Wood, Prof. G. L., M.A., Litt.D., The University, Carlton, N.3 1933
Wright, Prof. R. D., D.Sc., M.B., M.S., F.R.A.C.S., F.R.A.C.P., The University, Carlton, N.3 1941

Country Members

Adams, H. E., "Danedite," Weerite	1945
Baldwin, J. G., B.Sc., B.Agr.Sc., Commonwealth Research Station, Merbein	1949
Brown, W., c/o Bureau of Mineral Resources, 485 Bourke Street, Melbourne, C.1	1946
Buley, J. V., B.Sc., Engineering School, The University, Carlton, N.3	1946
Caldwell, J. J., c/o Geological Survey Office, Bendigo	1930
Corney, Mrs. A. D., B.Sc., 17 Ratho Street, New Town, Tasmania	1945
Currie, Mrs. Ian, "Seven Oaks," Euroa	1941
Felstead, Dr. J. G. R., P.O. Box 30, Horsham	1945
Glaessner, M. F., Ph.D., D.Sc., Geology Department, The University of Adelaide, Adelaide, South Australia	1939
Gloe, C. S., M.Sc., Irrigation and Water Supply Commission, Box 553H, G.P.O., Brisbane, Queensland	1944
Harris, W. J., B.A., D.Sc., P.O. Box 34, Warragul	1914
Hill, Dorothy, D.Sc., Geology Department, The University of Queensland, Brisbane, Queensland	1939
Hope, G. B., B.M.E., "Carrical," Hermitage Road, Newtown, Geelong	1918
Jenkin, J. J., National Museum, Russell Street, Melbourne, C.1	1945
Knight, J. L., B.Sc., Mines Department, Melbourne, C.2	1944
Mack, G., B.Sc., Queensland Museum, Brisbane, Queensland	1943
Mann, S. F., Melbourne Club, 36 Collins Street, Melbourne, C.1	1922
Martin, Miss Gwen J., B.Sc., 101 Waterdale Road, Ivanhoe, N.21	1946
Middleton, Dr. F. G., 79 The Esplanade, Geelong	1946
Payne, T. E. Neville, "Woodburn," Kilmore	1945
Quayle, D. S., 183 Greville Street, Prahran	1939
Rose, F. G. G., Division of Regional Planning, Post-war Reconstruction, Canberra, A.C.T.	1944
Trebilcock, Lieut. Col. R. E., M.C., Wellington Street, Kerang	1921
White, R. A., B.Sc., School of Mines, Bendigo	1918
Yates, H., M.Sc., School of Mines, Ballarat	1943

Associate Members

Aitken, Miss Y., M.Agr.Sc., School of Agriculture, The University, Carlton, N.3	1936
Alderman, A. R., M.Sc., Ph.D., F.G.S., Box 4331, Melbourne, C.1	1942
Ashton, D. H., B.Sc., Botany Department, The University, Carlton, N.3	1949
Bage, Miss F., O.B.E., M.Sc., Grove Crescent, Toowong, Brisbane, S.W.1, Queensland	1906
Baker, A. A., 52 Carlisle Street, Preston, N.18	1946
Bishop, J. J., B.A., Northcote High School, St. George's Road, Northcote, N.16	1950
Bottoms, E. A., 68 Robinsons Road, Hawthorn, E.2	1943
Brazenor, C. W., National Museum, Russell Street, Melbourne, C.1	1931
Broadhurst, E., M.Sc., 457 St. Kilda Road, Melbourne, S.C.2	1930
Bryan, T. C., 17 Madden Street, Albert Park, S.C.6	1950
Buckle, G., B.Sc., 2 Ontario Street, Caulfield, S.E.7	1945
Butcher, A. D., M.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.1	1936
Butler, L. S. G., No. 3 Los Angeles Court, St. Kilda, S.2	1929
Canavan, F., B.Sc., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1	1936
Carter, A. A. C., "Fairholm," 15 Threadneedle Street, Balwyn, E.8	1927
Carter, A. N., Box 2, St. Ronan, 10 Berkeley Street, Hawthorn, E.2	1947
Chapman, Brigadier W. D., M.C.E., "Hellas," Stawell Street, Kew, E.4	1927
Chapple, Rev. E. H., The Manse, Warrigal Road, Oakleigh, S.E.12	1919
Clifford, H. T., B.Sc., Botany Department, The University, Carlton, N.3	1949
Clinton, H. F., "Whitehall," 20 Bank Place, Melbourne, C.1	1920
Cochrane, G. W., M.Sc., Mines Department, Adelaide, South Australia	1945
Collins, A. C., 3 Lawrence Street, Newtown, Geelong	1928
Condon, M. A., M.Sc., 14 Blyth Street, Altona, W.18	1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot Road, Hawthorn, E.2	1919
Cookson, Miss I. C., D.Sc., 154 Power Street, Hawthorn, E.2	1919
Corbett, Miss M. A., B.Sc., 10 Clyde Street, Thornbury, N.17	1948
Coulson, A., M.Sc., 23 Sheridan Avenue, Frankston	1929
Court, A. B., Childs Road, Kalorama	1949
Cowen, Miss Margot E. H., B.Agr.Sc., Department of Agriculture, Palmerston North, New Zealand	1936

Crespin, Miss I., B.A., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T.	1919
Crohn, P. W., M.Sc., Mines Department, Melbourne, C.2	1946
Croll, I. C. H., M.Sc., 53 The Boulevard, Hawthorn, E.2	1934
Croll, R. D., B.Agr.Sc., 18 Russell Street, Camberwell, E.6	1940
Currey, D. T., 164 Ormond Road, Elwood, S.3	1948
Dadswell, Mrs. Inez W., M.Sc., 72 Florizel Street, Burwood, E.13	1939
Deane, Cedric, 461 St. Kilda Road, Melbourne, S.C.2	1923
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22	1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9	1946
Eadie, J. M., B.Sc., State Rivers and Water Supply Commission, 31 Flinders Lane, Melbourne, C.1	1949
Edwards, G. R., B.Sc., High School, Portland	1937
Elford, F. G., B.Sc., Dip.Ed., 76 New Street, Brighton, S.5	1929
Elford, H. S., B.E., c/o Tait Publishing Company, 349 Collins Street, Melbourne, C.1	1934
Fawcett, Miss Stella G. M., M.Sc., Botany Department, The University, Carlton, N.3	1937
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7	1949
Forster, H. C., B.Agr.Sc., Ph.D., 6 Glendene Avenue, Kew, E.4	1938
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16	1933
Gaskin, A. J., M.Sc., Geology Department, The University, Carlton, N.3	1941
Gladwell, R. A., 79 Cochrane Street, Elsternwick, S.4	1938
Gordon, Alan, B.Sc., c/o C.S.I.R.O., Yarra Bank Road, South Melbourne, S.C.4	1938
Gunson, Miss Mary, M.Sc., Zoology Department, The University, Carlton, N.3	1944
Haque, A. F. M. M., c/o Geological Survey, 25 Gymkhana Road, Quetta, Pakistan	1946
Hanks, W., 7 Lake Grove, Coburg, N.14	1930
Hardy, A. D., 24 Studley Avenue, Kew, E.4	1913
Hauser, H. B., M.Sc., Geology Department, The University, Carlton, N.3	1919
Head, W. C. E., 7 Farmers Street, Nhill	1931
Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia	1935
Hill, R. D., D.Sc., Physics Department, University of Illinois, Urbana, Ill., U.S.A.	1946
Hitchcock, W. B., National Museum, Russell Street, Melbourne, C.1	1949
Hogan, T. W., M.Agr.Sc., 22 Cornell Street, Burwood, E.13	1947
Holland, R. A., 526 Toorak Road, Toorak, S.E.2	1931
Holmes, A. J., B.Sc., 606 Glenhuntly Road, Caulfield, S.E.8	1949
Holmes, W. M., M.A., B.Sc., 1 Balmoral Avenue, Kew, E.4	1913
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21	1934
Hutchinson, R. C., B.Sc., Department of Agriculture, Rabaul, New Guinea	1939
Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7	1913
Jessep, A. W., B.Sc., M.Agr.Sc., Botanical Gardens, South Yarra, S.E.1	1927
Jones, L. H. P., M.Sc., Ph.D., Chemistry Department, The University, Carlton, N.3	1948
Kenley, P. R., B.Sc., 4 Anthony Street, Ormond, S.E.14	1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4	1942
Kilvington, T., M.Sc., Linden Farm, Upper Beaconsfield	1938
Law, P. G., M.Sc., 10a Copelen Street, South Yarra, S.E.1	1946
Lindner, A. W., B.Sc., Bureau of Mineral Resources, Canberra, A.C.T.	1949
McLennan, Assoc. Prof. Ethel, D.Sc., The University, Carlton, N.3	1915
MacPherson, Miss J. Hope, B.Sc., National Museum, Russell Street, Melbourne, C.1	1940
Manning, N., 733 Punt Road, South Yarra, S.E.1	1940
Melhuish, T. D'A., M.Sc., c/o Elliots & Australian Drug Pty. Ltd., Terry Street, Rozelle, N.S.W.	1919
Mitchell, A. W. L., B.Sc., 71 Radnor Street, Camberwell, E.6	1946
Mitchell, Miss J., National Museum, Russell Street, Melbourne, C.1	1949
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9	1945
Morris, P. F., National Herbarium, South Yarra, S.E.1	1921
Moy, A. F., B.A., Melbourne Boys' High School, Forrest Hill, South Yarra, S.E.1	1943
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, The University, Carlton, N.3	1940
Nye, E. E., College of Pharmacy, 360 Swanston Street, Melbourne, C.1	1932
Oke, C., 34 Bourke Street, Melbourne, C.1	1922
Osborne, N., c/o Australasian Petroleum Company, Port Moresby, Papua	1930
Pike, Miss K. M., B.Sc., Botany Department, The University, Carlton, N.3	1948
Pinches, Mrs. M., 8 Thomas Street, Brunswick, N.10	1943
Prentice, H. J., B.Sc., Strangways	1936
Pretty, R. B., M.Sc., 62 Glen Iris Road, Glen Iris, S.E.6	1922
Raff, Miss J. W., M.Sc., F.R.E.S., 116 Tooronga Road, Hawthorn East, E.3	1910

Richardson, Sidney C., 16 Brewster Street, Essendon, W.5	1923
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5	1948
Samson, H. R., M.Sc., Industrial Chemistry Division, C.S.I.R.O., Box 4331, Melbourne, C.1	1945
Schleiger, N. W., B.Sc., "Elmhurst," Napier Street, White Hills, Bendigo	1949
Seeger, R. C., 56 Jenkins Street, Northcote, N.16	1946
Shaw, N. J., 192 Victoria Street, West Brunswick, N.12	1950
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W.	1918
Shipp, A., "Gangort," Canterbury Road, Heathmont	1946
Singleton, O. P., M.Sc., Sidney Sussex College, Cambridge	1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6	1932
Stubbs, G. C., M.Agr.Sc., Plant Research Laboratory, Swan Street, Burnley, E.1	1943
Thomas, G. A., B.Sc., 39 Duffy Street, Ainslie, Canberra, A.C.T.	1944
Thomas, L. A., B.Sc., C.S.I.R.O., Stanthorpe, Queensland	1930
Trüdinger, W., 27 Gerald Street, Murrumbeena, S.E.9	1918
Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R.O., Cronulla, N.S.W.	1936
Tugby, D. J., National Museum, Russell Street, Melbourne, C.1	1949
Vasey, G. H., B.C.E., The University, Carlton, N.3	1936
White, Miss Lillian, B.Sc., 241 Domain Road, South Yarra, S.E.1	1947
Whitehead, Mrs. Sylvia, M.Sc., 48 Invermay Grove, Rosanna	1942
Whitehead, R. C., B.Sc., 48 Invermay Grove, Rosanna	1948
Woodburn, Mrs. Fenton, 21 Bayview Crescent, Black Rock, S.9	1930

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1949

The President and Council present to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1949. The following meetings of the Society were held:

March 10.—Annual Meeting. The following office-bearers were elected: President, Mr. P. Crosbie Morrison; Vice-Presidents, Professor J. S. Turner, Dr. F. L. Stillwell; Honorary Treasurer, Mr. R. T. M. Pescott; Honorary Librarian, Mr. F. A. Cudmore; Honorary Secretary, Dr. C. M. Tattam; Members of Council, Mr. D. A. Casey, Captain J. K. Davis, Professor E. S. Hills, Professor L. H. Martin, Professor W. A. Osborne, Dr. H. S. Summers, Professor O. W. Tiegs.

The following Members of Council continued in office: Professor E. W. Skeats, Professor S. M. Wadham, Professor R. D. Wright, Dr. R. T. Patton, Mr. W. Baragwanath.

The Annual Report and Financial Statement for 1948 were read and adopted.

At the close of the Annual Meeting an Ordinary Meeting was held. Paper: "The Geology, Physiography and Petrology of the Omeo District, Victoria," by P. W. Crohn.

April 21.—Lecture: "Missing Mechanisms in Evolution," by Professor W. A. Osborne.

May 12.—Lecture: "Heard Island," by Dr. A. R. Gilchrist.

June 9.—Lecture: "Some Observations on Recent Developments in the Mineral Sciences," by Dr. A. R. Alderman.

July 14.—Papers: "On the Terminology and Classification of Shore Platforms," by J. T. Jutson: "The Cyclic Landsurfaces of Australia," by Lester King (communicated by J. T. Jutson). "Petrology of the Cainozoic Basaltic Rocks of Tasmania," by A. B. Edwards. "The Geology of Picnic Point, Port Phillip Bay, Victoria," by Edmund D. Gill.

August 11.—Lecture: "The Meteorological Basis of Artificial Rain," by Dr. Fritz Loewe.

September 8.—Lecture: "Artificial Insemination of Animals," by Mr. G. W. Grigg.

October 13.—Paper: "Some Sooty Moulds Collected in Queensland," by Eileen E. Fisher. Lecture: "Overseas Soil Research Institutes," by Associate Professor G. W. Leeper.

November 10.—Special General Meeting. Amendments to the Laws of the Society were submitted and adopted.

At the close of the Special General Meeting an Ordinary Meeting was held. Paper: "Middle Devonian Corals from the Buchan District, Victoria," by Dorothy Hill.

December 8.—Papers: "Sandringham Sands—A Formational Name for Certain Tertiary Sediments in the Vicinity of Melbourne, Victoria," by Edmund D. Gill. "A Soil Survey of the Shire of Whittlesea, Victoria," by J. G. Baldwin. Lecture: "Land Utilization in the Shire of Whittlesea," by Mr. A. J. McIntyre.

During the year three members, one country member and eleven associate members were elected. The total membership of the Society on December 31 was 236.

The Council deeply regrets the loss, by death, of four members.

GEORGE WILLIAM SELBY was elected a member of the Society in 1889 and for the past few years held the honour of longest membership. He was a man of wide interests but perhaps best known for his pioneering activities in the electrical industries of Melbourne. His early boyhood was spent in Australia but in 1873 he went to England to complete his education. Even at this time he was interested in electrical experiments. Returning to Melbourne, he began work as a clerk but soon afterwards established his own business as an electrical engineer. He also carried on an accountancy business. He produced the second telephone to be used in Melbourne. In 1884 he became manager of the newly established Australian Electric Company and took a leading part in the struggle to popularize the use of electricity. In this same year he communicated to the Society a paper entitled "Electricity as a Motive Power on Railways." He was keenly interested in radio transmission and in 1896 sent a radio message from Brighton to Caulfield. He was the first to manufacture X-ray equipment in Melbourne. Outstanding on the accountancy side of his career was his service as auditor to the Broken Hill Proprietary Company for 59 years, from a year after its establishment up till 1945. He was a Fellow of the Institute of Chartered Accountants and of the Commonwealth Institute of Accountants. He died at the age of 92 on July 11.

WALTER JAMES PARR was born on September 3, 1893. He was educated at the Melbourne Continuation School and entered the State Public Service in 1910. He served in various departments, including the Treasury, Education and the Forests Commission. In 1932 he transferred to the Mines Department as Chief Clerk, later becoming Assistant Secretary, which position he held until his death. He served with the infantry in the A.I.F. throughout the 1914-18 war. He was elected an associate member of the Society in 1927 but later became a full member. He was Honorary Treasurer from 1941 to 1946, when failing health compelled him to relinquish this office. He was attracted to palaeontology through Frederick Chapman and devoted himself to the foraminifera, upon which he became the greatest Australian-born authority, acclaimed by his colleagues throughout the world. He contributed many papers to the Society, as sole author or in collaboration with Chapman or his friend A. C. Collins. He has also published in the journals of the Royal Societies of other States and in the Memoirs of the National Museum of Victoria. His last great work, carried out and completed while his health was failing, was upon the foraminifera collected during the last expedition of Sir Douglas Mawson to the Antarctic. He was a great palaeontologist and self-critic and would not publish any result until he felt confident of its validity. He died on August 21.

EDWARD CLARENCE EVELYN DYASON, B.Sc., B.M.E., was born at Bendigo on April 8, 1886. He was educated at St. Andrew's College, Bendigo, and at the University of Melbourne. His interests in mining turned to the administrative and financial sides and he was responsible for the effort to sustain gold mining in Bendigo against rising costs by the formation of the Bendigo Amalgamated Goldfield Co. in 1916. He founded the firm of Melbourne stockbrokers bearing his name and was chairman of the Stock Exchange in 1921. He was elected a member of this Society in 1913. He was the author of a number of

papers on economic subjects and joint author of "The Australian Tariff." He was president of the Economics section of the Australasian Association for the Advancement of Science in 1932. He gave his services freely to several government committees and was chairman of the Bureau of Social and International Affairs from 1930 to 1932 and again from 1934 to 1939. For the past few years he had been away from Australia but continued to serve the country in various ways. He had led the Australian delegation attending the British Commonwealth Relations Conference at Montreal and was returning to London from this conference when he died at sea on October 4.

ARNOLD EDWIN VICTOR RICHARDSON, C.M.G., M.A., D.Sc., B.Sc.Agric., was born in Adelaide in 1880. He was educated at the University of Adelaide (M.A., B.Sc.Agric.) and gained the degree of D.Sc. at the University of Melbourne in 1924. He was Assistant Director of Agriculture in South Australia from 1908 to 1910, becoming Director in 1911. He was Superintendent of Agriculture in Victoria from 1911 to 1924. Following upon investigations into agricultural education and research in U.S.A. and Canada on behalf of the Victorian Government in 1918, he became the first Dean of the Faculty of Agriculture and Director of the School of Agriculture at the University of Melbourne. He held the joint positions of Waite Professor of Agriculture and Director of the Waite Agricultural Research Institute in the University of Adelaide from 1924 to 1937. His work in agricultural research and education achieved for him a world reputation and he made important contributions to the knowledge of wheat cultivation in Australia. He was a member of the executive committee of C.S.I.R. since 1927, becoming Deputy Chairman in 1938 and Chief Executive Officer in 1946, retiring in 1949. In 1938 he was awarded the C.M.G. for his services to Australian agriculture. He was a past president of the Australian Institute of Agricultural Science, the Australian and New Zealand Association for the Advancement of Science, and the Graduates' Section, Melbourne University Union. He was elected a member of this Society in 1912 and served on the Council for ten years. He resigned during his absence in South Australia and was re-elected in 1938. He died on December 5.

The attendances at Council meetings were as follows: Mr. Crosbie Morrison, 9; Mr. Baragwanath, 11; Mr. Casey, 7; Mr. Cudmore, 9; Captain Davis, 2; Professor Hills, 9; Associate Professor Leeper, 5; Professor Martin, 0; Professor Osborne, 1; Dr. Patton, 1; Mr. Pescott, 11; Professor Skeats, 1; Dr. Stillwell, 10; Dr. Summers, 10; Dr. Tattam, 10; Professor Tiegs, 6; Professor Turner, 0; Professor Wadham, 5; Professor Wright, 0.

Professor Wright resigned from the Council early in the year and Associate Professor Leeper was elected in June to fill the vacancy. Professors Skeats and Turner and Captain Davis were granted leave of absence for the year because of visits abroad.

During the year 2,228 volumes and parts were added to the library.

Volume LXI of the Proceedings was issued in December. It is regretted that Volume LIX, part 2, and Volume LX are not yet off the press, but it is hoped that they will soon be available.

HONORARY TREASURER'S REPORT

The financial position of the Society appears to remain satisfactory, a credit balance of £676/8/6 appearing in the current account as at December 31, 1949, compared with a balance of £566/5/7 at the corresponding time the previous year.

In some ways, this may be regarded as a false and misleading balance, as with outstanding commitments of an overdue volume and one half of the Proceedings this balance will almost entirely disappear.

The principal items of expenditure this year were £387/10/- for the printing of Volume LXI of the Proceedings and £57/5/1 for library shelving. This latter item has only partly relieved the congestion in the library, but, because of shortage of supplies, complete relief cannot be expected for some considerable period. On the receipts side, a large number of members who were in arrears with their subscriptions have again become financial. It is only with the regular receipt of subscriptions that the work of the Society can be maintained efficiently.

It is pleasing to be able to report that the State Government raised its annual grant from £100 to £200. This will assist the work of the Society, which in the near future will have to face heavy commitments for repairs and maintenance.

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1949

RECEIPTS

Balance in Bank at 1/1/1949		£566 5 7
Subscriptions—		
Members	£168 0 0	
Associate Members	81 19 0	
Country Members	23 2 0	
Arrears paid up	65 2 0	
Advance Subscriptions	2 2 0	
		340 5 0
Rents—		
Commonwealth Government	£204 0 0	
Field Naturalists' Club	16 0 0	
Microscopical Society	12 0 0	
		232 0 0
Sale of Publications		127 14 4
Interest on Bonds		17 2 9
Grants and Donations—		
Government of Victoria		100 0 0
Sundries		7 6
		£1383 15 2

EXPENDITURE

Printing—		
Proceedings, Vol. LXI		£387 10 0
Salaries—		
Assistant Secretary	£24 0 0	
Assistant Librarian	11 0 0	
Hallkeeper	12 0 0	
Gardener	25 5 0	
		72 5 0
Light, Water and Gas		26 7 9
Telephone		13 6 6
Rates and Taxes		20 4 10
Insurance		6 15 0
Petty Cash		14 18 9
Postage		27 10 8
Repairs and Replacements		26 6 7
Meetings		9 4 0
Library Shelving, Subscriptions, etc.		101 6 3
Fire Brigade		1 10 0
Sundries		1 4
Balance in Bank at 31/12/1949		676 8 6
		£1383 15 2

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
February 17, 1950.

S. M. WADHAM } *Hon.*
G. L. WOOD } *Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1/1/1949	£67 9 9	Balance at 31/12/1949	£68 16 7
Interest to 31/5/1949	1 6 10		
	£68 16 7		£68 16 7

LIFE MEMBERSHIP FUND

Balance at 1/1/1949	£168 17 2	Balance at 31/12/1949	£171 18 2
Interest to 31/5/1949	3 1 0		
	£171 18 2		£171 18 2

HOWITT MEMORIAL FUND

Balance at 1/1/1949	£115 2 1	Balance at 31/12/1949	£121 5 1
Interest on Bond	3 17 6		
Savings Bank Interest to 31/5/49	2 5 6		
	£121 5 1		£121 5 1

T. S. HALL MEMORIAL FUND

Balance at 1/1/1949	£77 3 0	Balance at 31/12/1949	£78 13 10
Interest to 31/5/1949	1 10 10		
	£78 13 10		£78 13 10

BOOK-BINDING FUND

Balance at 1/1/1949	£110 7 4	Balance at 31/12/1949	£112 11 4
Interest to 31/5/1949	2 4 0		
	£112 11 4		£112 11 4

Accounts and Pass-books relating to each of the above Funds have been severally examined and found correct, and the Bank Certificate of Possession of Bonds amounting to five hundred pounds (£500) Savings Certificates to the face value of two hundred and fifty pounds (£250) and Fixed Deposit of two hundred pounds (£200) has also been inspected.

February 17, 1950.

R. T. M. PESCOTT, *Hon. Treasurer.*

S. M. WADHAM, } *Hon.*
G. L. WOOD } *Auditors.*

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PROCEEDINGS

OF THE

ROYAL SOCIETY OF VICTORIA

NEW SERIES

VOLUME 63

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20 October 1951

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CONTENTS OF VOLUME 63

Papers read before the Society during the year 1950 and edited under the authority of the Council. The authors of the several papers are individually responsible for the accuracy of the statements made and the soundness of the opinions given therein.

1

THE GEOLOGY OF THE LOWER WERRIBEE RIVER, VICTORIA

By M. A. Condon, B.Sc.

[Read 13 April 1950]

Abstract

The Werribee River downstream of the Bacchus Marsh basin has cut a gorge through an extensive lava field consisting of older sheet-flows, probably poured out from an east-west fault-fissure, and younger tongue-flows from central vents of various types. For the succession of basalt flows and interbedded pyroclastics the name 'Exford Volcanics' is proposed. The Exford Volcanics are up to 400 feet thick and rest on the slightly eroded surface of Tertiary marine clays, sands and limestone of Balcombian age. The surface of the lava field has been so little eroded as to constitute a virgin volcanic terrain, displaying many features characteristic of a basaltic lava field. This lava field occupies the north-western corner of the Port Phillip Sunkland and it is suggested that the north-eastern boundary of that Sunkland is a fault, running north-north-west through Williamstown, for which the name 'Gellibrand Fault' is proposed.

Introduction

The Lower Werribee River runs from Bacchus Marsh, 32 miles W.N.W. of Melbourne, to Port Phillip Bay, a distance of about 25 miles. The general direction of flow is south-easterly, and after leaving the Bacchus Marsh basin the river flows in a narrow gorge about 100 feet deep through a lava plain.

The area described in detail was surveyed geologically for the State Rivers and Water Supply Commission as the first part of a geological survey of the Werribee River catchment area, for purposes of water supply and soil conservation.

The geological plan was based on the parish plans of the Victorian Lands Department. Traverses were made by pace and compass, and levels were obtained by surveying aneroid corrected by means of a barograph. Form lines were drawn in the field and therefore the contours, though not accurate, give a good representation of the shape of the surface. Bore records of the Mines Department were used in drawing the sections.

Previous Work

The Lower Werribee River area was mapped by the Geological Survey of Victoria in 1860 to 1861. Published Quarter Sheets covering this area comprise numbers 8 S.W., 20 N.E., 20 S.E., and 20 N.W.

Despite its proximity to Melbourne, this area received no further attention from geologists until 1902, when Kitson described the area, including a list of fossils found in ejected blocks on Mount Mary. In the same year Thiele and Grant listed the fossils from the clays above the lignite in the Altona coal shaft and correlated these deposits with the clays of Balcombes Bay.

In 1918 Fenner wrote a long and detailed account of the physiography of the Werribee River catchment. He described the Rowsley Fault in detail and briefly mentioned the volcanoes of the lower plains but did not describe them. In 1924 he described the Bacchus Marsh basin and its development.

Keble mentioned the extensive lava field of the Werribee plains in his paper on lava residuals in 1918.

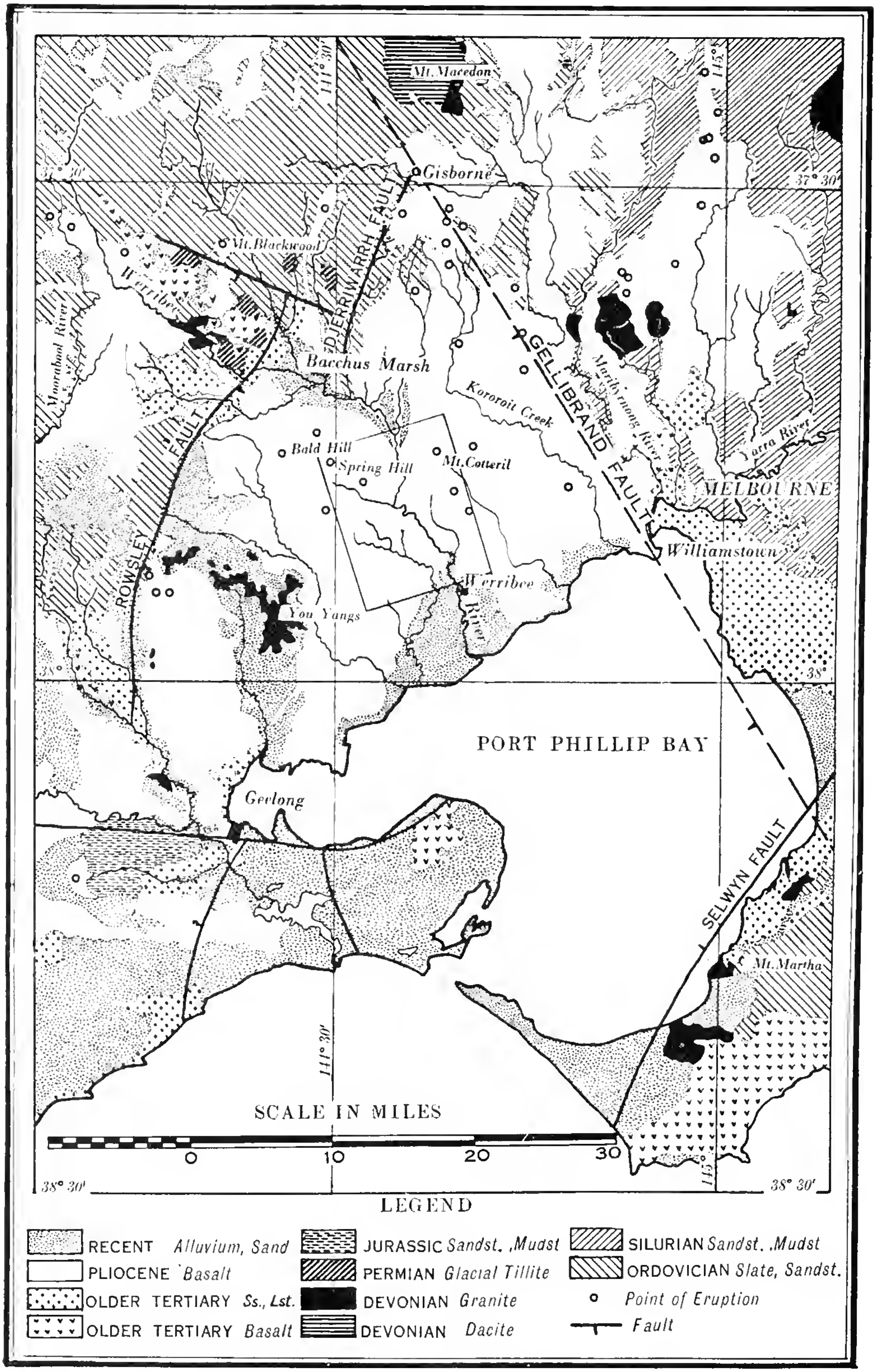

FIG. 1.—Geological Map. Rectangle outlines area shown in Fig. 2.

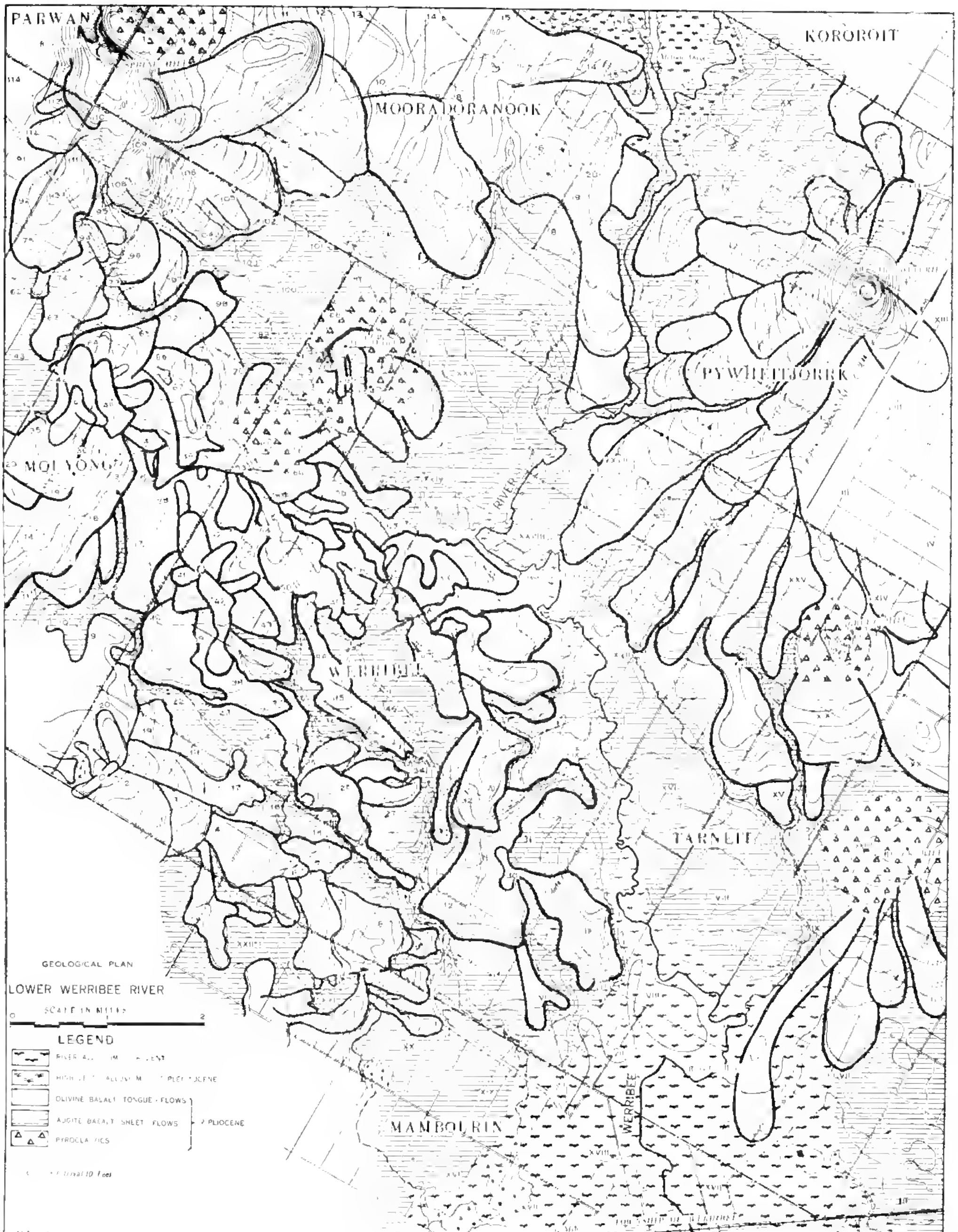

FIG. 2.—Geological Plan, Lower Werribee River.

Herman in 1922 mentioned the Werribee lignites in his report on Victorian brown coals, stating that the Altona lignite has Oligocene marine beds above and below it, but did not discuss the reason for the statement.

Coulson in 1938 described the two main types of basalt in the area—the Olivine Basalt (Ballan Type) of the vents and tongue-flows and the Augite Basalt of the lower sheet-flows—and placed them both in the Pleistocene.

Hills mentioned the basalt of the Bacchus Marsh district in his paper on the age of the Cainozoic Volcanic rocks of Victoria (1939). He stated that these basalts are almost certainly Pliocene.

Singleton (1941) in his "Tertiary Geology of Australia" described the lignites, sands and clays of the Parwan-Altona area as Oligocene, overlain by marine Balcombian clay and limestone.

Parr listed typical Balcombian foraminifera assemblages from limestone above the top lignite and from clay between the top and main lignite seams (1942).

Kenny in 1947 described the Bacchus Marsh Coal Mine, Parwan, where development work had been done on two seams of brown coal prior to the outbreak of fire.

Forbes in 1948 described the soil erosion in the catchment above the Melton Reservoir.

Thomas and Baragwanath (1949) mentioned the Altona-Parwan brown coal in describing the brown coals of Victoria.

Structural Geology

The valley of the Werribee River, downstream of Bacchus Marsh, forms part of the large structural unit known as the Port Phillip Sunkland. This is essentially a fault trough, the boundary faults being the Rowsley Fault to the west, the Selwyn Fault to the east, and to the north a group of poorly-defined faults running roughly from Darley to Whittlesea. There is probably another boundary fault running from near Frankston north-north-west through Williamstown. To the east of this line there are extensive outcrops of Cainozoic sediments of Balcombian and Kalimnan age, and of Silurian bedrock. For some distance to the west of this line from Williamstown to Gisborne, only Newer Volcanics outcrop. Bores at West Newport

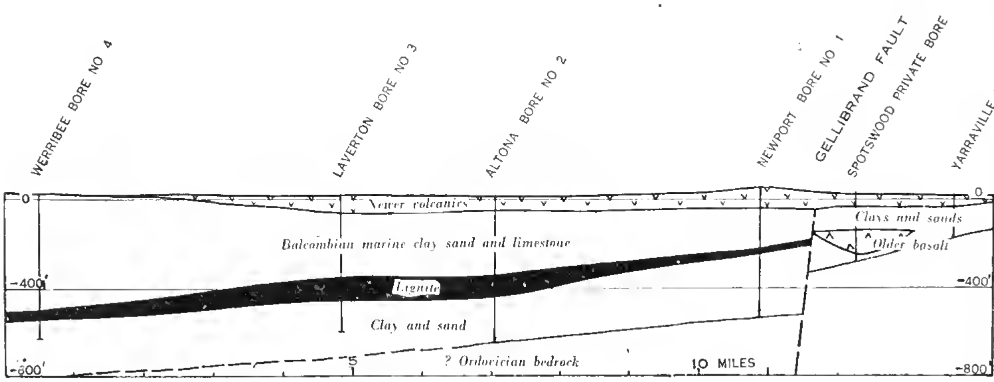

FIG. 3.—Sketch Section, Werribee to Yarraville.

and Altona show Balcombian sediments down to 330 feet below sea level and bedrock at 550 feet below sea level (Fig. 3). This level in the Newport bore is 350 feet below the level of the bedrock in the Yarraville bore 3 miles to the north-east.

This difference is quite at variance with the gradients of the bedrock between the Newport and Altona bores and between the Yarraville and Spotswood bores and appears to indicate the presence of a fault with a throw in the Tertiary sediments of about 150 feet. The name 'Gellibrand Fault' (from Point Gellibrand at the south end of the Williamstown peninsula) is proposed for this fault. The southern projection of the line of this fault passes along the steep eastern shore of Port Phillip Bay and (on the south-east side of the Selwyn Fault) passes to the north of the Ordovician sediments in the Mornington Peninsula. The extension of this line to the north passes through the very marked concentration of points of eruption in the Gisborne district and is in line with the Elphinstone-Harcourt edge of the Mount Alexander granodiorite. It seems possible that the Gellibrand Fault may be a Palaeozoic fault of large throw causing at least part of the displacement of the Ordovician-Silurian boundary from near Sydenham to the Mornington Peninsula.

The Port Phillip Sunkland is of late Tertiary origin, although the boundary faults developed at different times: the northern group and the Gellibrand Fault in the Palaeozoic, Selwyn's Fault in early Tertiary and Rowsley Fault in late Tertiary times.

The Drainage System and Its Development

The Lower Werribee River flows easterly from Bacchus Marsh to Exford and then south-south-easterly to Port Phillip Bay. The Lerderderg River and Coimadai Creek enter the river from the north and the Parwan Creek from the south within the Bacchus Marsh basin. The Djerriwarrh and Toolern Creeks enter the river from the north between the basin and Exford. There are no significant tributaries downstream of Toolern Creek.

The valley of the Werribee River is markedly asymmetrical about the river both as to areas and topography and, apart from the accident of naming, it is obvious that the main stream above the Bacchus Marsh basin is the Lederderg.

The author agrees with Fenner in ascribing the development of the Bacchus Marsh basin to river erosion in the soft Tertiary sediments (Fenner 1919, 1925), but prefers another interpretation of the history of the drainage system. The coastal plain of Tertiary sediments almost certainly had a marked effect on the form of the pre-Newer Volcanic drainage. The edge of this plain was along a line from near Lal Lal in the west to Coimadai and thence to near Keilor. On the surface of the coastal plain the courses of the streams would be determined by the general southerly slope, by the position of streams reaching the coastal plain from the highlands and by minor depressions in the surface of the plain. There are many flows, both confined flows and sheet-flows and tongue-flows of unconfined type, in the Newer Volcanic episode.

With these facts in mind, the physiographic history of the Werribee catchment may be set out as follows:

1. Development of a peneplain probably continuing into early Tertiary times.
2. Uplift and commencement of dissection of the peneplain by the rivers already established on its surface.
3. The Tertiary Port Phillip sedimentary basin was initiated as a fresh water basin in which were deposited sands, clays and vegetable material which later formed lignite.
4. Older volcanic lava flows filled some of the valleys on the land surface.
5. Further subsidence caused a marine invasion of the Port Phillip basin and the deposition of the Balcombian and Kalminan clays, limestones and sands.
6. These sediments were exposed by uplift and the main streams developed

inherited courses as extended consequent streams on the southerly-sloping surface of the resulting coastal plain, which stretched southward from about the latitude of Ballan.

At this stage, it seems reasonably certain that the ancestor of the Upper Werribee, above Ballan, joined by the Korweinguboora and Korjamumnip Creeks, flowed over the plain to meet the Moorabool near Morrison's: that the Dales, Korobeit, and Myrniong Creeks entered on the plain independently as very small streams and finally joined one or other of the main streams far to the south; and that the Lerderderg River and the 'Ancient Djerriwarrh' and 'Ancient Coimadai' Creeks maintained independent southerly courses over the coastal plain. In the soft Tertiary sediments, the valleys cut by these streams would be narrow and deep. Such a valley, filled with basalt and cut through by the Werribee, occurs just below the mouth of the Korkuperrimul Creek. It is probably the valley cut into the Tertiary sediments by the 'Ancient Lerderderg' River.

7. The Newer Volcanic episode commenced, the early flows rapidly filling the narrow valleys in the Tertiary sediments and spreading out as sheet flows. As a result the shape of the resulting surface was determined more by the locations of the vents and the general slope of the surface of the coastal plain than by the position of the former valleys, except in the bedrock area where the valleys were well-defined, with high interfluves. In these valleys, lateral streams (Keble 1918)—Werribee, Myrniong, Korkuperrimul, Goodmans, Pyrete, Djerriwarrh—developed at the edge of confined lava flows. All the streams from Ballan to Korkuperrimul were diverted to the east by the basalt, and joined together, and the new stream (the Upper Werribee of the present) joined with the Lerderderg to flow south over the sheet flows which still reflected the slope of the underlying coastal plain.

8. At about this stage, the Rowsley, Greendale and Spring Creek faults became active and scarps were developed along these faults with consequent increased activity of streams on the upthrow blocks and deposition of extensive fault aprons at the base of the scarps.

9. The easterly course of the Werribee below Bacchus Marsh was not established until the late stages of vulcanicity when tongue-flows were poured out from Bald Hill (Balliang East) and Spring Hill. These flows blocked the south-flowing streams which were forced to develop an easterly course along the northern margin of the numerous tongue flows from these two vents. The diversion was almost repeated by a junction of flows from Spring Hill and Mount Cotteril but after forming a lake, the river, now joined with the Coimadai, Djerriwarrh and Toolern Creeks, was able to cut through the basalt bar and establish a course which was largely determined by the interdigitating tongue-flows from Spring Hill and other vents on the west and Mount Cotteril on the east. Westerly flows from Bald Hill also turned the Parwan Creek into the Werribee at this stage.

10. While the river was slowly cutting down through the hard basalt in the sections between the mouth of the Djerriwarrh Creek and Werribee township, the five streams in the Bacchus Marsh area were able to cut out the wide basin in the soft Tertiary sediments. By this time, the Rowsley scarp was well developed and the streams flowing over it were actively eroding deep gorges. Material from this source and from the attack on the sides of the Bacchus Marsh basin provided abrasive material for the river's attack on the basalt, which was further helped by the eustatic drop in sea level during the Pleistocene ice ages.

11. A subsequent rise in sea level caused alluviation of the lower part of the river valley and the formation of a deltaic deposit downstream from about 3 miles north of Werribee. Later fluctuations of sea level exposed much of this delta and

caused the river to cut a deep channel through this alluvium, caused alluviation of this channel and erosion through this newer alluvium. These fluctuations of sea level were probably accompanied by fluctuations in rainfall, high sea level (caused by high global temperatures melting the polar ice caps) being accompanied by high rainfall.

The Physiography of the Cobbledicks Ford District

This district is a lava plain with volcanic hills. The surface is divided between very rocky areas and areas of rich red soil, the latter being used for growing hay, the former only for grazing sheep. Along the river, the alluvial flats support small dairy herds and have been developed in some places into market gardens. The population is sparse especially to the west of the river where a large part of the surface is occupied by outcropping basalt. There are no flowing streams on the plain surface and stock must depend on rain water trapped in small dams or on ground water raised by windmill. The ground water is brackish but quite suitable for sheep. In most of the district the only vegetation is grass, either native or introduced, with an occasional she-oke. These are some areas of well-grown eucalypt (grey box), but over most of the plain the only trees are those in small plantations. These appear to grow reasonably well, and provide valuable shelter for stock. More general planting of trees as wind-breaks would help to reduce wind velocities at the surface, and thus minimize wind erosion which, while not very obvious, is occurring.

(1) The Volcanic Hills

The most obvious feature of the landscape is the number of isolated hills. These have a variety of forms which may be included in three main types, as follows:

(a) *The lava cone.* Mount Cotteril is an almost perfect example of the volcanic cone in which the shape is that of the geometric cone. In the case of Cotteril, this form has been achieved by the radial arrangement of a great number of tongue flows, with practically no explosive phase intervening. The lip of the crater has been built up first in one part and then in another, so that the flows were fairly evenly distributed around the circumference, and, in this way, the cone was built up equally on all sides. It is possible that the core of this hill may be of scoria, as without an initially elevated crater, it is unlikely that a cone would be developed.

(b) *The lava dome.* There are several hills in the district which have the form of a lava dome. The biggest of these is Spring Hill (R.L. 700 feet). Smaller examples include One Tree Hill (505 feet) in Crown Allotment 42, Parish of Mouyong, and the unnamed hills in Crown Allotments 41 and 52, and in Crown Allotment 1, Parish of Werribee. The geometric form of the lava dome is a segment of a sphere, and is thought to be due to the building up of the dome, particularly in its early stages, exclusively from lava. In nearly all cases, there is evidence of explosive activity late in the building of the dome, but this does not affect the general shape.

(c) *The scoria dome.* There are no pure scoria hills in this district, but the two hills of Mount Mary (Plate I, fig. 3) and Black Hill are essentially scoria domes with but few flows of lava.

Geometrically, the scoria dome is a segment of a sphere. Typically it rises very abruptly from the country on which it rests, has steep sides and flattish top.

Besides these three main types, the following, though smaller, are distinct, in origin and form.

(d) *Parasitic cone.* On the south-east flank of Spring Hill is a small parasitic lava dome, with later flows from Spring Hill diverted around it. There are several

parasitic vents which have not developed cones. These small domeshaped outcrops of hard, columnar basalt are not lava blisters since they have no connection with the flows through which they protrude, and usually occur close to a well-established vent. It is thought that they are probably small parasitic vents which never quite succeeded in extruding lava. Examples include one in C.A. 42, Parish of Mouyong (west of One Tree Hill), one in C.A. 51, Parish of Werribee, and three close together in C.A. 14, 19 and 20, Parish of Mouyong.

(e) *Lava ridge.* Running from Crown Allotment 58 to Crown Allotment 20B, Parish of Werribee, is a ridge of lava up to 30 feet above the adjoining country. This ridge, which has several low saddles, has no traceable connection with any point of eruption, although several small flows appear to originate at the ridge. It appears possible that this ridge has developed from a fissure-vent. In the same line, but further to the west, a small scoria dome occurs (in Crown Allotment 62, Parish of Werribee). This may be on the same fissure, but at this point the activity has been chiefly explosive (although a few small flows occur).

(f) *Lava blister.* In several cases, near the distal end of a tongue-flow, a low hill of lava occurs, in obvious continuity with the flow which surrounds it (e.g. in Crown Allotment A of Section XX). This is believed to be due to the arching up of the solidified outer surface of the flow by the pressure of still-fluid lava within and presupposes the development of a lava tunnel along the flow to give the necessary pressure.

On the crests of Mount Cotteril and Greek Hill there is an interesting structure. At the top of Mount Cotteril there is a steep face of hard dense basalt some 15 to 20 feet high. The top surface of this basalt dips in towards the centre of the crest, generally at low angles but on the north side at an agle of about 30°. Near the centre of the saucer-shaped crest is a thin flow of basalt with centripetal dip. At Greek Hill the interbedded basalt flows and scoria appear in a steep face on the north-eastern side dipping towards the south-west at about 10°. Two thin flows with centripetal dip can be followed around in a circular outcrop, but lower flows, outcropping in the face, do not outcrop elsewhere.

There appear to be several possible explanations. First, that the steep-sided cap was originally surrounded by tuff which has since been eroded away, that in the final stage of activity the lava solidified in the vent without overflowing, and then collapsed in the centre when lava withdrew from below. However, the evidence in the district is of very little erosion of pyroclastic material even on steep slopes.

Secondly, much the same series of events may have occurred, without any pyroclastic rim, and then either the central plug was forced up some 20 feet above the last lip, or the sides of the cone settled by that amount, the plug remaining stationary.

Finally, there is a possibility that the structure may be due to the upwelling and partial withdrawal of near-solid lava which was too viscous to overflow.

The upthrusting of the plug after the last effusive activity would account for almost all of the observed features on both Mount Cotteril and Greek Hill.

Edwards and Crawford (1940) ascribed rather similar steep-sided caps in the Gisborne district to erosion. Although the Gisborne cones are possibly older than those in the Exford district, and erosion has been effective in the basalt of the Gisborne district, it seems possible that those caps are of similar origin to that of Mount Cotteril.

It has been suggested (Thomas 1948) that these inward-dipping structures are 'diatremes.' By definition however, a diatreme is a hole, cylindrical or funnel-shaped, drilled through solid rock by gaseous explosion (Daubree 1890). Evidence of a

funnel-shaped vent does not alone establish the existence of a diatreme. Since at both Mount Cotteril and Greek Hill a vent had been in existence during the building of a large lava cone and a composite cone respectively, the term 'diatreme' is not applicable to this structure. Both Hack (1942) and Rust (1937) describe diatremes, respectively funnel-shaped (occupied by sediments and lava flows) and cylindrical (filled with agglomerate). This does not depart from Daubree's original nomenclature. In most of the vents of the Werribee Plains, the throat consists of a lower diatreme (opened by explosion) and an upper part built up by successive flows and pyroclastics. Exceptions to this, where the diatreme is at the surface, include the crater at the north end of Spring Hill and the double crater two miles north-west of that.

(2) Depressions

Almost as characteristic of the lava plain as the hills, although not as obvious, the numerous depressions are diverse in form and in mode of origin. The main types are as follows:

(a) *Subsidence depressions.* This depression is usually very shallow as compared with its area, often large (e.g. 40 acres in lot A16, Mooradoranook), and usually occurs on the top surface of a tongue-flow. Sections XI and XX, Pywheitjorrk, have some fourteen of these subsidence depressions. They are caused by the sagging of the surface which can result from the collapse of a tunnel in the basalt beneath, or by consolidation of underlying tuff beds. They are sometimes scattered apparently at random, but in some cases appear to have a definite linear arrangement (e.g. those in sections 27 and 28, Tarneit). It may be that this linear arrangement is a reflection of a lava tunnel, the roof of which has collapsed at a number of points along its length. As against this, no definite evidence of tunnel formation has been seen in the river gorge, so that the linear arrangement may be accidental.

(b) *Interflow depressions.* These are usually flat-bottomed and surrounded by lava flows. They occur where flows either from different vents or from the same vent approach one another, but meet only at isolated points, so that an area of the older surface is left exposed between the flows and becomes a swamp because there is no outlet to the drainage. Examples include depressions in Crown Allotments 63 and 9-10, Parish of Mouyong, 18, 25 and XIX A Werribee, XX D Tarneit.

(c) *Craters.* Most of the vents do not have any crater, but on the north flank of Spring Hill there is a large crater, probably in part at least, due to explosion at a late stage in the eruptive history of this volcano. To the north of this also, there is a large double crater, the road from Exford to Balliang passing along the ridge between the two craters.

(d) *Sites of former hot springs* (Plate I, fig. 3). Scattered over the surface of the lava plain are small depressions, which are very consistent in form. They consist of a depression up to several acres in area, but usually less than one acre and often only 20 feet in diameter. The depression is from one to two feet deep (below the level of the surrounding surface). The bottom of the depression consists of black or grey clay or clay loam usually with nodules of magnesite, sometimes with small boulders and fragments of basalt, usually limonite-coated. On the downhill side of the depression, or in very level areas completely surrounding it, is a level ridge of black clay loam up to one foot above the adjoining surface of the plains. From its characteristics, it is suggested that this type of depression is the site of former hot springs or fumeroles of the dying phase of vulcanicity. The low ridge is thought to be due to the transfer of soil from the water channel to the point where, on account of the very gentle slope, the velocity of the water would be reduced. The difference

in colour and texture between this feature and the surrounding soil is thought to be due to chemical change brought about by materials dissolved in the hot water. There is usually no sign of sand either in the depression or in the soil of the ridge—an indication that the large particles of sand probably sank into the water channel and only the finer clay and silt particles were carried by the water of the spring. No features which could be ascribed to geyser action were seen, and it is thought that if these had existed the evidence would still exist since in general there has been little erosive destruction of minor features in the surface soil. Some of the deeper 'hot spring' depressions, particularly those with a definite water-course leading away from them, may be sites of geysers, but definite evidence is lacking. The water of the springs which formed these depressions is thought of as having been hot because under ground water conditions which exist and which were probably similar when the springs were flowing, positive pressure from below would be required to bring the water to the surface from the water table, which is generally only slightly above sea level, and up to 200 feet below the surface, where these spring sites occur. The only likely cause of this pressure is steam produced by the residual heat of vulcanicity. The water tends to be carried to the surface up the vertical joint cracks by steam bubbles, in much the same way as an air-lift pump lifts water by means of compressed air (Addison 1934). The steam bubbles in order to persist must be in equilibrium with the surrounding water which, therefore, must be close to the boiling point, and which would be kept at that temperature by the supply of superheated steam from below.

There is no deposit of travertine or other precipitate around the depressions. The magnesite nodules in the soil may have derived from the water of the hot springs.

(3) The River Gorge

The Werribee River flows in a steep-sided gorge cut through the gently undulating lava plain. The course of the river, as of even the smallest water-courses on the plain, has been pre-determined by the final shape of the lava field. In general, the lower course of the river was determined by the flows from Bald Hill, Spring Hill and Mount Cotteril. Flows from the two former forced the river along to the east and a relatively low gap between the Spring Hill flows and the Cotteril flows determined its southerly course. The final course between the outlet from the Bacchus Marsh flats and Exford was established in the alluvial material deposited in the basalt-dammed lake which covered this area. The detailed position of the gorge is essentially superimposed on the older sheet flows through which it is cut, having being determined by small differences in level in the alluvium, when the lake was drained by erosion of the basalt bar, which was located in Crown Allotment X, Pywheitjorrk, and Allotment 20 of A, Mooradoranook. From this point, the river developed as a lateral stream at the edge of the more recent flows from Spring Hill, Cotteril, Black Hill and the numerous small vents in the Parish of Werribee. In the vertical-jointed basalt cut horizontally by beds of tuff and scoria, it is thought that the main erosive activity was probably waterfall erosion such as can be seen in the hanging valleys of the smaller tributary gullies in this district. It seems likely that there would be developed a series of waterfalls each one initiated by a bar of hard basalt. There is some indication of this in the profile of some of the spurs, but only in the Toolern Creek is there very good evidence in the form of large flat shoulders high above the river bed. There has been little erosion of the gorge since the deposition, in the bottom, of the older alluvium. Prior to this, the river was entrenched in a pseudo-meandrine course—the meanders having no relation to the graded condition of a flood plain tract, but being produced by the interfingering

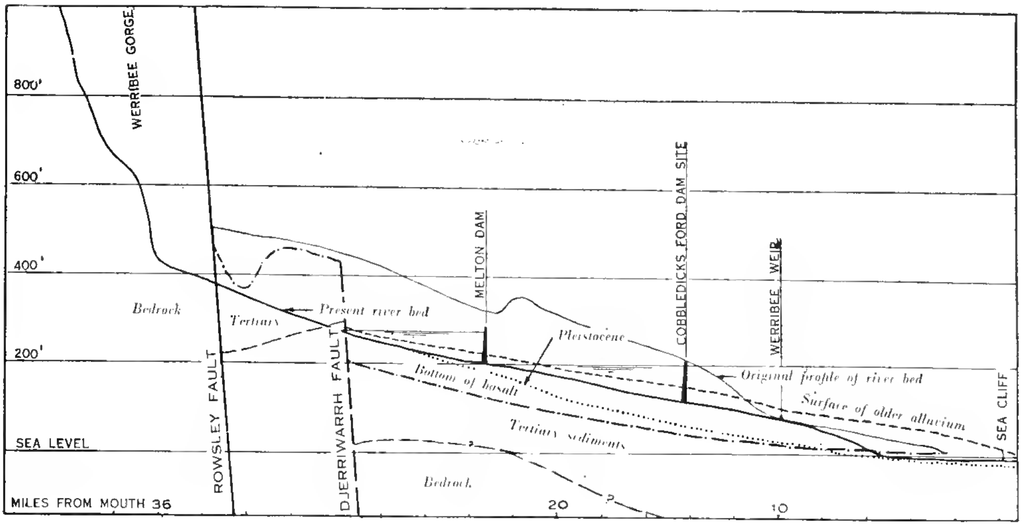

FIG. 4.—River Profiles Past and Present.

of flows from either side. The 'meanders' were actively migrating downstream and many sharpened spurs resulted, e.g. Crown Allotments 27B, 28D and 28C, in the Parish of Tarneit. Since the deposition of the older alluvium, the energy of the river has been so reduced that no further migration has taken place. The older alluvium forms a terrace some 30 feet above river bed. A lower terrace some 20 feet above river bed occurs in the newer alluvium. A third terrace, in the newer alluvium, about 10 feet above river bed, has been covered by recent floods and is still in process of formation.

(4) Minor Drainage

The minor drainage, on the surface of the lava plain, is essentially radial to the vents. The individual watercourses, in which water flows only after heavy, high-intensity rain, are lateral to the tongue-flows which generally radiate from the vent. Where sheet-flows form the plain surface the drainage is more haphazard, being determined by minor irregularities in the surface. The scoria hills have very little effect on the drainage—a reflection of the permeability of the scoria, rain usually soaking in rather than running off.

Geology of the Lower Werribee Valley

Ordovician Sedimentary Rocks

Thin-bedded slates and sandstones of Lower Ordovician age outcrop in the valley of the Djerriwarrh Creek almost to its junction with the Werribee River and at the bottom of the steep slopes at the east end of the Bacchus Marsh basin. The fault junction between the Lower and Upper Ordovician sediments runs along the valley of the Djerriwarrh Creek. The nature of the bedrock beneath the Werribee Plains is not known. The presence of large fragments of reef quartz in the basalt in some places suggests that the bedrock is of Ordovician sediments with their accompanying quartz reefs. No fragments of Ordovician sediments were observed in the basalt or pyroclastics.

Tertiary Sediments

Unconformably overlying the Ordovician sediments is a deposit of fresh-water and marine sediments, up to 700 feet thick. Sources of information about these sediments include the Mines Department logs of bores at Newport, Altona, Werribee, Parwan and Mouyong; the list of fossils described from the first Altona coal shaft (Thiele and Grant 1902); ejected blocks found on Mount Mary in the Parish of Werribee (Kitson 1902); Parr's description of the fauna from Bore No. 7, Parwan (Parr 1942); and outcrops in the Bacchus Marsh basin. The list of fossils from the Altona coal shaft includes 203 species of Mollusca, 180 of which occur at the type locality of the Balcombian Stage (Hall and Pritchard 1902). Ejected bloeks from Mount Mary, in which fossils are poorly preserved, contain sufficient well-preserved casts to establish the Balcombian age of these blocks (Kitson 1902). The material from the Altona coal shaft certainly came from above the coal, and is separated from it by a 'coarse water-worn gravel' which is unfossiliferous. Herman (1922) states that the Altona coal has marine Oligocene both above and below it. Singleton (1941) states that 'it is likely that the bulk of the Yallourn series is pre-Miocene as are probably the lignites, sands and clays of Altona and Parwan,' and that 'though all occurrences of lignites are not necessarily on the same horizon, in general they agree in being antecedent in the main to the principal or Barwonian marine deposits, and it is, therefore, not unreasonable to refer the bulk of the lignite series to the Oligocene.' W. J. Parr (1942) described the micro-fauna from Bore No. 7, Parish of Parwan, where, in a cream limestone and grey clay above the upper ligneous clay, he found a foraminiferal assemblage typical of the Balcombian Stage, including Lepidocyclines from the limestones. The Balcombian fauna was repeated in another bed of grey clay beneath this ligneous clay. This would appear to fix the Altona-Parwan coal as part of the Balcombian Stage, and to point to an alternation of marine and estuarine conditions in this area during the Balcombian Age.

The Newer Volcanic Rocks

The Newer Volcanic rocks of the Lower Werribee Valley comprise basalts of closely related types, and pyroclastics—tuff, scoria and agglomerate in thin beds between flows. The Newer Volcanic period of activity in Victoria probably commenced in the Pliocene Epoch and continued, with some quiet periods, into the Recent Epoch (Hills 1939). The vulcanicity was undoubtedly connected with the earth movements which elevated much of south-eastern Australia to its present height and produced such large faults as the Bogong Fault, the Rowsley Fault and many of the Gippsland faults. There are two distinct phases in the vulcanicity here as elsewhere in Victoria (Mahony and Grayson 1910)—the earlier phase of sheet-flows, probably from fissure vents, and the later phase of tongue-flows from central vents. The Lower Werribee area is an excellent example of an extensive lava field (Keble 1918), having completely covered the pre-basaltic surface.

(a) The earlier phase: The vents from which the earlier flows poured out are not known. There is a progressive thinning of these lower flows from north to south along the gorge of the Werribee River between Exford and Cobbledicks Ford. The lower tongue-flows from Mount Cotteril and Spring Hill flowed chiefly to the north and south indicating that the surface of the sheet-flows probably sloped in these directions from these points. These vents were possibly situated on an east-west ridge (above a fissure vent). The linear arrangement of the volcanic vents of Spring Hill, Mount Cotteril and Mount Atkinson makes it appear possible that

a fault zone and extrusion channel could occur along that line. However, no sign of such a vent (Fuller 1927) has been seen in the river gorge downstream of Melton Dam. The earlier phase of volcanic activity is characterized by widespread sheet-flows of large horizontal dimensions, but thin (up to 50 feet thick) in relation to their extent. As the surface over which these flows travelled was the very gently-sloping coastal plain of the raised marine sediments, the very great extent of these flows implies very great fluidity in the lava, as well as the extrusion of very large volumes of lava in a short time. The two conditions would be mutually helpful since rapid extrusion of large volumes of lava would lessen the degree of cooling in the passage through the crust and tend to produce hotter and, therefore, more fluid lava at the surface, and the more fluid lava would be more readily poured out at relatively high velocities. These earlier basalts contained large amounts of gas—as shown by the very vesicular nature of the chilled base and top of the flows—and this gas would help to maintain the fluidity of the lava. There are several distinct sheet-flows in this area, usually with tuff, scoria or agglomerate between the individual flows. Between two of these sheet flows there is a fossil soil with the horizons of a mature soil and buckshot gravel near the surface indicating that there were appreciable intervals between individual extrusions. The sheet-flows are chiefly of pyroxene basalt, although the lower flows are of olivine basalt.

(b) Later phase: At a late stage in the period of vulcanicity, volcanic cones were built up around relatively small crater-vents. These cones are of four types—lava cones (Mount Cotteril), lava domes (Spring Hill), scoria cones (Mount Mary), and composite cones (Black Hill). They are the most conspicuous feature of the lava-plain landscape, standing out prominently in spite of their low height—only some 400 feet above the surrounding plain. The olivine and iddingsite basalt from these cones were poured out in the form of tongue-flows of relatively small volume, elongated in the direction of travel and with a thickness appreciable in relation to width (up to 5 per cent). A characteristic of these tongue-flows is that, at least toward the distal end, they stand up above the older surface with quite steep sides and front, but fairly flat top, so that they are tongue-shaped in section as well as in plan. The rocks of this later phase have been so little affected by erosion that the individual flows can be traced quite clearly. The only places where erosion is marked is along the river gorge and along some of the tributaries.

'Exford Volcanics'

Resting on the eroded surface of the unconsolidated marine clays and sands of possibly Kalimnan age is a succession of basalt, tuff and agglomerate for which the name Exford Volcanics is proposed. The name is taken from the property between the Werribee River and the Toolern Creek at their junction. The Exford Volcanics, outcropping in the Werribee River gorge downstream of Melton Dam and on the plain on either side of the river, comprise sheet-flows of olivine basalt, augite basalt and iddingsite basalt and tongue-flows of olivine basalt together with thin beds of pyroclastics between flows. Maximum total thickness is about 600 feet at Mount Cotteril. They are almost certainly Upper Pliocene in age but may range into the earliest Pleistocene (Hills 1939).

Details of the succession through the Exford Volcanics, from oldest to youngest, follow:

(a) Resting on the marine sediments is a deposit of tuff of variable thickness (up to 11 feet in Bore 4, Mooradoranook) probably representing the explosive phase which often initiates a volcanic period.

(b) Above this and also very variable in thickness (up to 50 feet thick) is a sheet-flow of olivine basalt which filled the valleys of the streams crossing the coastal plain, and spread out across much of the plain. The top of this flow is exposed in the bed of the creek which enters the Werribee River in section XXIV B, Parish of Werribee. Here it is hard, dense, only slightly oxidized, grey in colour, with small phenocrysts of light green olivine. It probably corresponds with the 'hard basalt' recorded in many bores at the bottom of the volcanic rocks.

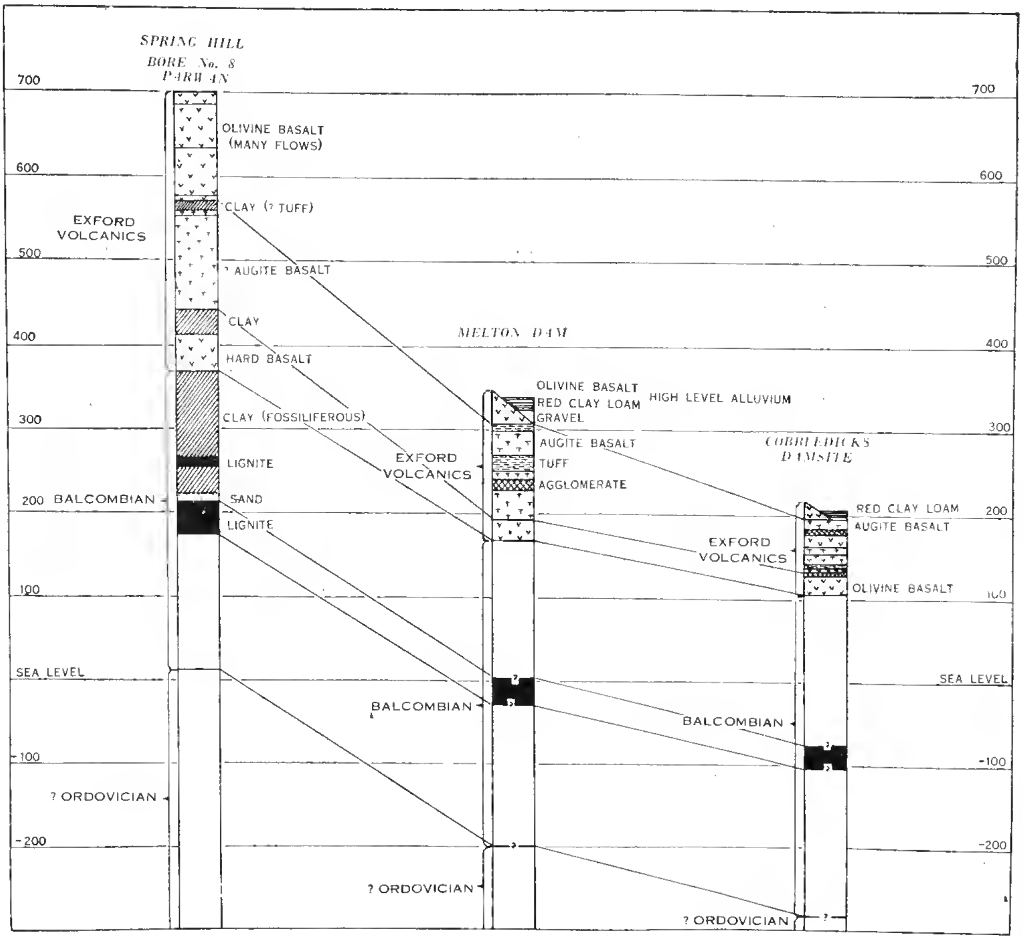

Fig. 5.—Stratigraphical Columns.

(c) Resting on the surface of the olivine basalt is the lowest flow of augite-basalt, usually between 20 and 30 feet thick. Where exposed, this flow is usually decomposed with only fresh plums remaining in the friable brown decomposed basalt. A good exposure of slightly weathered rock occurs in the lower part of the spillway of the Melton Dam. The fresh rock is hard, dense, dark green and medium-grained crystalline, although the chilled lower selvedge shows very few phenocrysts, indi-

cating that the crystallization occurred after extrusion. The top surface of the flow is very vesicular and is usually less decomposed than the body of the flow.

(d) On top of the lowest augite basalt rests a deposit of tuff and clay varying in thickness from 6 inches to 12 feet. The top part of this deposit is a fossil soil derived from tuff. Typical profile is as follows: Up to 4 feet of tuff usually red, and sometimes 'prismatic' consisting of polygonal prisms up to 1 inch in diameter, and up to 1 foot long. This tuff rests on the surface of the lowest augite-basalt, and in places has entered along joint cracks to a depth of 10 feet. The tuff passes up gradually into a red-brown clay subsoil up to 2 feet thick which in turn passes up into a yellowish clay soil up to 2 feet thick and then into a whitish soil (up to 1 foot thick) with much buckshot gravel. The development of this mature soil necessitates a rather lengthy period free of volcanic activity. In a few places quartz gravel with pebbles up to 1 inch diameter rests on the surface of this soil. The importance of this fossil soil lies in its demonstration that the newer volcanic period was not one of uninterrupted activity such as has been assumed by some writers, but that not only were there many and separate flows, but also periods of quiet, during which processes of erosion and deposition would continue without superimposed effects of vulcanicity.

(e) Resting on the surface of the fossil soil and usually 'baking' it for a depth of 2 or 3 inches is the thickest flow in the succession, the second augite-basalt flow. This flow, of titan-augite basalt, is about 50 feet thick at Exford, but thins towards the south so that at Cobbledicks Ford it is only 15 feet thick. A common feature of the lower part of this flow is a development of tachylitic pillow basalt. The pillows are up to 18 inches in diameter, with up to 2 inches of tachylite on the surface of each pillow.

The pillows show characteristic radial jointing. The tachylite is weathered yellow on the outside, but is mostly very fresh. This feature is very well seen on the right side of the Toolern Creek Valley just upstream of the Exford Bridge (Plate I, fig. 5). Similar exposures occur at intervals down the gorge and appear to be associated with thick developments of the fossil soil in areas which are relatively low.

Below the pillow lava near Exford Bridge there are quartz gravels resting on the surface of the fossil soil.

It is probable that these places were water-courses prior to the outpouring of this flow, and that damming of the streams by small tongue-flows just prior to the main outpouring produced small lakes into which the basalt was extruded from the chilled advancing end of the lava. These pillow lavas are very significant in respect of water storage since they may continue for appreciable distances, and are very pervious. This type occurs near and downstream of the junction of Toolern Creek and the Werribee River, on the left side of the river valley in lot A of 27, Parish of Tarneit, and on the right side of the river valley just downstream of Cobbledicks Ford. The basalt of this flow in general is decomposed with fresh residual plums of hard, dark green, crystalline basalt. Where the pillow lava does not occur, the bottom of the flow is very vesicular, and usually the vesicles are filled with carbonates. The top of the flow is usually very vesicular and a feature of the flow as a whole is the amount of foundered skin which occurs, sometimes giving the appearance of separate flows. In a few exposures in the river gorge, the upper part of this flow is hard, oxidized and columnar, so that it seems possible that the more generally observed decomposed rock is a surface development.

(f) Resting on the vesicular surface of the second augite-basalt sheet-flow is a well developed zone of pyroclastics—up to 3 feet of scoriaceous agglomerate at the bottom, 1 to 10 feet of well-bedded tuff and lapilli above (Plate I, fig. 4). The agglomerate is rather sporadic in occurrence. In its thicker occurrences (as at

Staughtons Bridge) it consists of pieces of scoriaceous and dense basalt up to 3 inches in diameter in a dark red-brown ground mass of tuff, clay and volcanic glass. The bedded tuff is of a buff colour in beds from about 6 inches to $\frac{1}{8}$ inch thick. The thicker beds consist of scoriaceous yellow tachylite, basalt fragments, fragments of quartz and sandstone, waterworn quartz sand, and mineral fragments. The thinner beds contain the same constituents in smaller size. In a few cases there is some grading from coarse to fine. The general appearance of the material is very pervious, and not consistent with deposition under water. Furthermore, the bedding follows irregularities in the underlying surface with very little variation in thickness, so that it can be stated with confidence that this material is a sub-aerial deposit, and that such sorting as does occur is due to the variation in rates of settling through the air. There is no sign of weathering in the top layers of this deposit, which, therefore, must have been exposed for only a short time before the next flow covered it. This zone is rather pervious and likely to cause losses by seepage from a reservoir. The bedded tuff is a relatively weak rock, although it does have 40 feet of basalt (equalling about 50 lbs. per square inch) resting on it without noticeable failure.

(g) On top of the bedded tuff, and apparently following it with very little time-break, is the upper flow of titan-augite basalt—generally hard, oxidized and columnar, but occasionally showing the complete decomposition of the lower flows. This flow is rather thin near Exford, but thickens southward, increasing from about 15 feet at Exford to some 30 feet at Cobbledicks Ford. Like the other augite-basalt flows, it has a dense centre and a vesicular top and bottom, the latter usually chilled. This flow contains many fragments of reef quartz.

(h) A bed of scoria up to 3 feet thick rests on the surface of the upper augite-basalt flow. This consists of rough, scoriaceous basalt blocks up to 6 inches in diameter in a very open arrangement.

(i) The very ropy and scoriaceous bottom of the lower flow of iddingsite basalt rests on the bed of scoria. This flow is from 5 to 20 feet thick, is often very decomposed in its outcrop, and usually shows platy as well as columnar jointing. The rock is generally vesicular, is dark grey when fresh, and contains phenocrysts of iddingsite up to 5 mm. in diameter. It outcrops at or just below the lip of the gorge all the way between Melton Dam and Staughtons Bridge.

(j) Above the lower iddingsite basalt is a second flow of similar type. Usually there is no pyroclastic rock between, although in places a thin layer of scoria occurs. The upper iddingsite basalt is from 5 to 10 feet thick, generally less weathered than the lower, hard, dark grey, vesicular, columnar and somewhat platy, although not as noticeably as the lower flow. Like the lower flow, it contains phenocrysts of iddingsite, but also contains some olivine.

(k) A thin layer of tuff or scoria usually occurs between the upper flow of iddingsite basalt and the flow of olivine basalt which occurs above it. In the cliff face of the river gorge, olivine basalt occurs in discontinuous outcrop, where the ends of flows from either side have been cut by the river. At no place is there evidence of the same flow of olivine basalt occurring on both sides of the valley—the river everywhere has developed around the edge of the flow and has nowhere cut across it. The olivine basalt is a hard, microvesicular blue-grey rock with small phenocrysts of olivine many of which are iddingsitized. The rock is usually quite fresh, and jointed into columns up to 6 feet in diameter. As many as three flows can be seen in the exposed face on the valley side, although many more flows occur nearer the points of eruption. The olivine basalt is the most suitable rock for use as concrete aggregate or for rock fill, since it is unweathered, whereas most of the other types are generally not fresh.

As will be seen from the above description of the volcanic rock sequence, there is relatively little variation in petrological type in this district. This is in marked contrast to the Gisborne district, where a much smaller eruptive phase was productive of many more types (Edwards and Crawford 1940). The reason for this may be found in the examination of the chilled selvedges of the various flows which give an approximate picture of the state of crystallization of the lava when it was poured out. The selvedge of the middle augite-basalt flow shows very small phenocrysts of augite and iddingsitized olivine in a dark glass. This indicates that crystallization had not progressed very far before extrusion and that, therefore, differentiation had not become effective. This is an indication that the temperature of the magma was sufficiently high to prevent crystallization of alkali minerals, and that a channel was opened to the surface otherwise than by cupola development. It is suggested that one or more of the faults in the Port Phillip Sunkland opened a channel between the magma and the surface and allowed the extrusion of vast amounts of undifferentiated and uncrystallized 'olivine-basalt magma' which, because of its high temperature and great fluidity, covered large areas as sheet-flows before crystallizing and coming to rest. The main channel may have been the eastward extension of the Spring Creek Fault at the south of the Ballan Sunkland, along the line of which the later vents of Bald Hill, Spring Hill, Mount Mary and Greek Hill are located.

Weathering

Basalt, because of its mineralogical composition and open jointing, is very susceptible to rapid weathering. The iron oxides, olivine and mineral glass which occur quite generally are very rapidly oxidized when meteoric solutions come in contact with them, and because of the columnar jointing, the interior of flows is subject to the attack of surface water more quickly than are most other rock types. This rapidity of weathering is reflected in the condition of the basalt. Badly weathered and slightly weathered flows are interbedded, while the freshest flow of all is the olivine basalt of the tongue-flows on the plain on either side of the gorge. In general, it is probable that the more decomposed flows were exposed at the surface for a relatively long time before being covered by the later flow while the less weathered flows were covered almost immediately by the flow above, and in this way protected from attack by surface water. The olivine basalt at the surface probably owes its freshness to the relatively short period which has elapsed since its extrusion. In the fresh basalt, much of the iron present is ferrous iron (about 7 per cent. of the rock is FeO). When weathering starts, the iron is oxidized and the lime and magnesia is almost entirely removed (McCance 1932). Some of this is probably reprecipitated in vesicles as geodes, but most of it is carried away in the ground water and is the reason for the brackish nature of that water. The oxidation of the olivines and hydration of the iron ores produce internal stresses in the rock, which cause minute cracks which further help the access of water to the interior of the rock. Continued oxidation and hydration produce disintegration of the rock into its component minerals and results in the friable brown decomposed rock which is so typical of the weathering of basalt (the 'salamander' of quarry-men). None of the basalt of this district has been weathered to a clay in the way that many of the older basalts have.

An interesting feature related to the weathering is the variation in soil development. On slopes which face from south-east to westerly there is generally a relatively good cover of dark humous clay loam, while on slopes facing north-west to easterly there is only a cover of rock debris with very little soil or vegetation. As this difference is not related either to rock type or to slope (except that very steep slopes are generally barren), it is believed to be due first to the greater amount of rain received

on the slopes facing generally south-westerly, as compared with those facing generally north-easterly (most heavy rain in this district coming from the south and west), and secondly, to the lower evaporation from the slopes facing south-westerly which do not receive so much direct sunshine and are not exposed to the hot drying north winds of summer.

Jointing

All of the flows exposed at the damsite have been jointed into rough columns although, in the more decomposed flows, the joints are largely lost in the general disintegration of the rocks. Basalt solidifies at a temperature of about 1000° Centigrade, and since the thermal coefficient of expansion of basalt is about 0·000005 per degree Fahrenheit, the linear contraction involved in cooling to air temperature would be about 1 per cent. Hence, with joint columns about 5 feet in diameter, the joints would be about $\frac{1}{2}$ inch wide. This gives the physical reason for the vertical jointing in basalt—vertical contraction can take place without cracking, but in the relatively great horizontal dimension of a flow, the contraction cannot occur by movement over the surface, and, therefore, cracking along vertical planes occurs. The joint cracks are open equally throughout the flow, and are one of the reasons for the demonstrated permeability of basalt in the mass. For the same reason, a basalt flow has practically no tensile strength in a horizontal direction, although its compressional strength, particularly in the vertical sense, is quite high (about 18,000 lbs. per square inch).

Permeability

The total interconnected void space in jointed basalt, as indicated above, is about 2 per cent. of the volume of the flow, or about 1 per cent. of the area of a vertical section. These percentages may be reduced by the infilling of the joints by clay or secondary mineral deposit. An important feature of these joint cracks in relation to permeability is their relative uniformity (as compared for instance with the voids in a gravel). As a result of this, the permeability of basalt is much higher than the void ratio might indicate. Confirmative evidence of the high permeability of the basalt in this district is seen in the level and gradient of the water table. Between Bore No. 1, Kororiot, and Bore No. 1, Pywheitjorrk, there is a difference of level in the water table of 84 feet in a distance of 180 chains, a gradient of less than 1 per cent. The gradient between Bore No. 1, Pywheitjorrk, and the river 80 chains to the west (0·3 per cent.) is thought to be due to the river having developed a perched water table above the general surface of the ground water in the basalt.

In relation to the storage, the joint space in the basalt can cause appreciable initial losses, and there is almost certain to be a continual loss to the ground water, until such time as the basin is covered by a layer of silt. The ground water level is generally at, or slightly below, river level—there is apparently very little flow from the ground water into the stream. When water is stored to full supply level, there would be a difference in level between the stored water and the ground water of up to 100 feet, with the consequent possibility of steep hydraulic gradients and large water losses. Some of the water would be recoverable when the level of stored water fell, but much would pass into the ground water and flow directly to Port Phillip Bay as such. From Exford to Cobbledicks Ford there are a number of outcrops of tachylitic pillow basalt. These are probably located in an old watercourse. The farthest downstream of these outcrops seen, at R.L. 180 feet in the valley wall immediately to the south-east of the Cobbledicks Ford, would provide a very pervious channel for water stored to R.L. 200 feet. The Melton Reservoir does not give

a satisfactory comparison to the Cobbledicks storage in relation to losses through the basalt, since the basalt outcropping in the Melton storage is nearly everywhere decomposed so that the joints are closed. Such losses as occur are probably due to permeable scoria layers, although there is evidence, in Bore No. 2, Mooradoranook, of a gravel-filled deep lead which may draw water from the reservoir.

Stability

As stated above, the hard fresh basalt is very strong in vertical compression, but the vertical joints make it very weak in tension. The horizontal flows with pyroclastic material between them, in addition to the strength characteristics of the basalt, make the volcanic series very susceptible to slip failure, which is further encouraged by the tendency towards very steep slopes being developed by erosion. Landslips are quite characteristic of the valley sides and as they have occurred so frequently under natural conditions, it is most likely that under the conditions imposed by the storage many more landslips will develop.

Faulting

There is no evidence of faulting in the volcanic flows, either at the damsite or in the storage area (between Exford and Cobbledicks Ford), except in one place where there is a displacement of perhaps 10 feet in the middle and lower flows. At the damsite the rocks are reasonably well exposed, so that any major fault would be noticeable in the displacement of flows. The bedded tuff forms a quite valuable marker bed and, although it follows minor irregularities of the older surface, it is sufficiently regular to indicate any major displacement. There are, however, probably many faults of appreciable throw in the underlying Tertiary sediments, as shown in the marked displacement of these beds, with their noticeable lignites, in the two bores, Nos. 7 and 8, Parwan, where there is a vertical displacement of 34 feet in a horizontal distance of 20 chains.

Post-Basaltic Sediments

(A) *High level alluvium*

Covering the top surface of the basalt from Exford northwards to near Melton Railway Station, westward to Parwan Railway Station, and north-westward to the Melbourne-Ballarat Road on the Djerriwarrh-Coimadai interfluve, is an alluvial deposit consisting of coarse gravel, sand and sandy clay loam of a total maximum thickness of 15 feet (Plate I, fig. 2). The gravel is well rounded and consists of quartz, quartzite, hornfels, and few basalt pebbles. The pebbles range in size up to 9 inches in diameter. The sand, generally above the gravel, is clean quartz sand. Above the sand is a layer of clay loam, which, near the surface, is a dark red-brown sandy clay loam. This deposit rests on the surface of the iddingsite basalt sheet-flows and against the side of some of the olivine basalt tongue-flows. It was probably laid down in a lake formed by the diversion and damming of the Upper Werribee drainage by the tongue-flows from Bald Hill, Spring Hill and Cotteril. This lake overflowed at a point just south of Exford, and as the river cut through the bar at that point, the alluvial deposit was exposed and the streams established courses on the surface of the deposit, and cut through it and into the basalt beneath.

(B) *Clay loam of the lava plain surface*

Covering the entire surface of the basalt, except at the edges of the flows and in the bottom of the larger watercourses, is a deposit of soil of variable thickness (up to 10 feet). The thicker deposits generally occur on the surface of the older sheet-

flows, while the surface of the later tongue-flows usually has a much thinner deposit. The profile of the thicker deposits as shown in the road cutting on the east side of the river at Staughtons Bridge is shown in Fig. 6. Resting on the scoriaceous surface of the sheet-flow of augite-basalt is 3 feet of light grey clay with fragments of tuffaceous material, small fragments of basalt and nodules and veins of magnesitic material. It is believed that this clay is a decomposed, very fine tuff, resulting

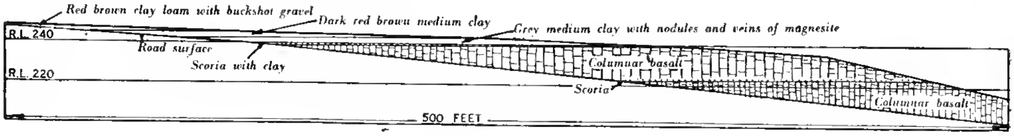

FIG. 6.—Road Cutting, Staughtons Bridge, East Side.

from distant explosive activity. This material is similar to the sticky grey clay which is so characteristic of the surface in the Footscray district, where it has no cover of red clay loam. Above the grey clay at Staughtons Bridge is a layer about 2 feet thick of dark red-brown clay with magnesitic nodules. This appears to be quite a distinct layer and appears to be largely tuffaceous. The surface layer of about 2 feet of red-brown sandy clay loam, in which the sand is a well rounded quartz sand, and which contains buckshot gravel, is probably in part tuffaceous in origin, and in part loessal, part of the sand having been windborne and deposited with the volcanic ash. This sandy clay loam is the only soil which appears on the surface of the later tongue-flows. Much of the sand may have been blown out with the volcanic ash (from the Tertiary sands underlying the basalt), and in this regard it is interesting to note that the proportion of sand in the sandy clay loam increases appreciably in the vicinity of Mount Mary, one of the few large scoria cones in the district. This red-brown clay loam is of vital economic importance to the district, since it is only where it covers the basalt to a sufficient depth that cultivation is possible. It is a rich soil, but very shallow, and it is at present being allowed to erode by wind and water action. The total effect to date is very small, but every strong hot north wind carries a quota of soil from this district to the sea. Erosion by water action is rare as in general the soil is sufficiently pervious to prevent large runoff, but where stock or vehicular traffic compact this soil and prevent absorption of rain, erosion can be very rapid. There are enough small erosion gullies scattered around the district to cause concern to anyone interested in conserving the vital top soil not only for this generation but for many to come. Active measures should be taken to halt the present gullies, and to prevent the development of new ones. In this generally dry area, high intensity rain can do untold damage if positive measures are not taken in advance to reduce the velocity of water running off and particularly to eliminate vertical drops.

(C) *Older alluvium*

An alluvial deposit up to 90 feet thick occupies the bottom of the valleys of the Werribee River and of the Toolern Creek. This deposit, according to evidence from bores at Cobbledicks Ford, has up to 60 feet of sand and coarse waterworn gravel at bottom and up to 30 feet of red brown sandy loam above. The red-brown sandy clay loam overlying the gravel probably was deposited during a period of reduced river flow, as compared with that which carried the gravels. It appears to be a fairly uniform deposit both vertically and in its occurrence along the river valley,

although there is a noticeable variation from more sandy to more clayey type from Exford to the Werribee Delta, which is composed chiefly of red-brown clay loam. Near the damsite this deposit is a sandy loam with some layers of clay loam—probably an ideal material for use in a rolled-earth section of the dam. Like the gravel below it, the sandy loam derives chiefly from the bedrock areas to the north and west of the Werribee Plains, and but little from the basalt. Just above the Werribee Weir this deposit has completely filled the valley cut in the basalt, and spread out over the surface of the basalt in the form of a delta. It seems probable that this delta was built up above sea-level as a flood-plain deposit. The deposit shows remarkably little bedding except in its lower levels where beds of sand and gravel appear. No marine fossils were seen, or have been reported. It seems probable that if the delta had been formed under the sea there would have been more obvious bedding and marine shell beds. The eroded valley in the basalt which underlies this delta is filled with gravel and sand, and is continuous with the gravel of the deposit in the gorge. This bed of gravel is an important aquifer and during the drought of 1944-46, when insufficient water for irrigation was available from Melton Reservoir, water from bores penetrating this deep lead enabled production to be maintained on many properties. The water is quite suitable for irrigation in strong contrast to the ground water in the basalt, which has a high salt content. This probably means that the water in this aquifer is derived directly from the river and does not receive an appreciable addition from the ground water, and therefore the hydraulic surface of the water in the aquifer must be at or above that of the adjoining ground water in the basalt. The seaward edge of this delta is being eroded by wave action—one of the few parts of the western shore of Port Phillip Bay which is suffering erosion (Plate I, fig. 1).

(D) *Newer alluvium*

A valley has been cut about 40 feet deep into the older alluvium. This has been refilled to a depth of about 20 feet by an alluvial deposit of grey gravelly sandy loam, clay and sand. This deposit is still being built up, every large flood dropping sand on the surface of the terrace and building up the bed of the river channel. The whole deposit has probably been built up in this way, so that there is no continuity in any of the beds. This alluviation may be connected with a eustatic rise of sea level accompanying the melting of the polar ice caps, which is still progressing.

The river almost never reaches the level of the older alluvial terrace, so that its activity is confined to the valley eroded in the older alluvium. Within this valley the river wanders, and even in the past 100 years has changed course in several places.

(E) *Marine sands and clays*

Along the tidal stretch above the mouth of the river and along parts of the foreshore (east of Little River), there are very recent deposits of sand, peat and clay with marine shells. The deposits nearest the foreshore consist of a beach ridge, some 4 feet above normal high tide level, consisting of quartz sand and broken shells, and on the shoreward side a salt-water swamp with a floor of peaty clay. The beach ridge probably began as a submarine sandbank which was raised above sea level in a storm. The raised sandbank cut off the area behind it except during storms, when large quantities of seaweed were deposited in the flat area behind the sand ridge, producing peat on decomposition. Offshore, sandbanks are forming and their shape in plan and section would appear to conform with the plan and section of the sand ridges at Altona shown by Hills (1940).

Siltation

The catchment of this proposed reservoir includes some of the worst areas for water-erosion in the State (Forbes 1948). The capacity of Melton Reservoir has been reduced from 19,000 to 15,400 acre-feet in 31 years, a loss of 3,600 acre-feet from a catchment of 424 square miles, or an average loss of 0·013 feet over the whole catchment. There has been as yet no concerted attack on this problem, only emergency measures designed to check stream erosion in the vicinity of roads, structures or valuable land having been undertaken. Although Forbes considers that the Parwan catchment (the worst area in the whole catchment) is 'not necessarily overstocked,' he apparently separates the domestic stock (chiefly sheep) from wild stock (rabbits). In terms of soil conservation this cannot be done, the total use of available vegetation being the important factor. As erosion is progressing, and vegetation regeneration is not occurring, it seems obvious that the area is overstocked.

It may be thought, in terms of the proposed Cobbledicks Ford storage, that Melton Reservoir would act as a silt trap, and that siltation is not likely to be a serious consideration. However, from observation of flood flows past Melton Dam, it seems obvious that a very large amount of the finer sediment, up to sand size, is being carried through the Melton Reservoir and would be dropped in the lower storage.

Unfortunately, there appears to be no quantitative record of the silt content of this flood water. There is only one recorded sample of water from Toolern Creek—the only other contributor to the proposed storage. On April 22, 1947, a flow of 10 cusecs had a suspended solids content of 236 parts per 100,000—an indication that erosion is serious in this part of the catchment also. By far the greatest amount of erosion is effected in very short time during periods of high intensity rainfall and, if only flood flows (of more than 1,000 cusecs) are considered, the average amount of silt dropped in Melton Reservoir from flood flows was 480 parts per 100,000 for the years 1917-1947. This, of course, includes bed-load as well as an unknown part of the body-load. It seems reasonable to assume that flood flows past Melton may carry at least 200 parts per 100,000 of suspended solids, while Toolern Creek's total flow (chiefly of flashy nature) would certainly carry at least as much. Of this, at least 100 parts per 100,000 would be dropped in a reservoir downstream of Melton Dam. As flood flows total about 50 per cent. of total flows, and the average annual flow at Cobbledicks Ford is 50,000 acre-feet, the minimum average annual siltation rate would probably be of the order of 25 acre-feet (about one-quarter the rate for Melton). The lower rate is due to Melton's acting as a trap for the bed-load (boulders and gravel), which forms an appreciable part of the sediment. This rate would make the half-life of this storage some 400 years (under present conditions), but as the half-life of Melton is probably only 100 years from construction, and as with increased sedimentation of the reservoir the percentage of silt carried over increases the actual '50 per cent.-life' of the proposed storage may be as little as 200 years (under present conditions in the catchment). This emphasizes the urgent need for widespread soil conservation measures in this catchment. They should be implemented without delay and long continued, so that the present active erosion may be halted, and proper land usage adopted to prevent a continuation of the history of the past century. Unless this is done, any storage on the Lower Werribee is foredoomed to failure by sedimentation, in an historically short period.

Acknowledgments

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Explanation of Plate I

Fig. 1 (State Rivers Registered No. 5098).—Wave-cut cliffs in delta alluvium, Parish of Deutgam.
Fig. 2 (7968).—Gravel pit in high-level alluvium, Section XX, Parish of Pywheitjorrk. (a) Gravel and sand, (b) clay, (c) dark red-brown clay loam.
Fig. 3 (7966-7).—'Hot-spring' depression, Section XX-A, Parish of Werribee. Figure standing in centre of depression. (a) Crescentic mound on lower side, (b) Mount Mary (scoria cone) on skyline.
Fig. 4 (7971).—Bedded tuff, Staughtons Bridge. (a) Agglomerate, (b) bedded tuff.
Fig. 5 (7970).—Pillow basalt, Toolern Creek.

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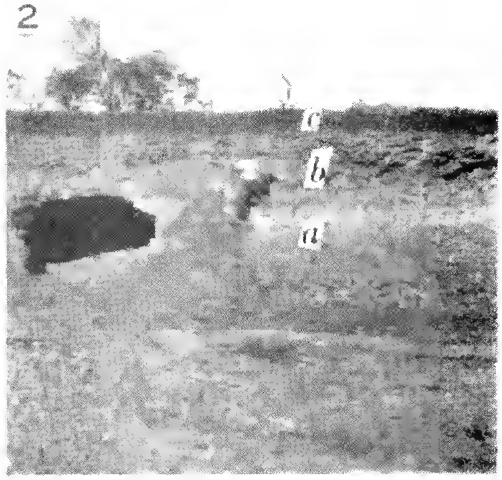

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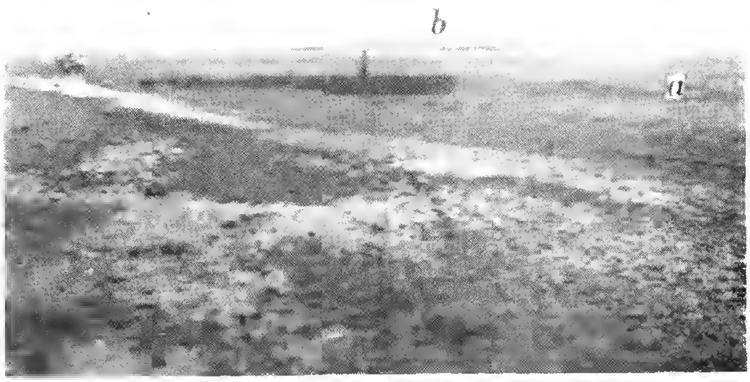

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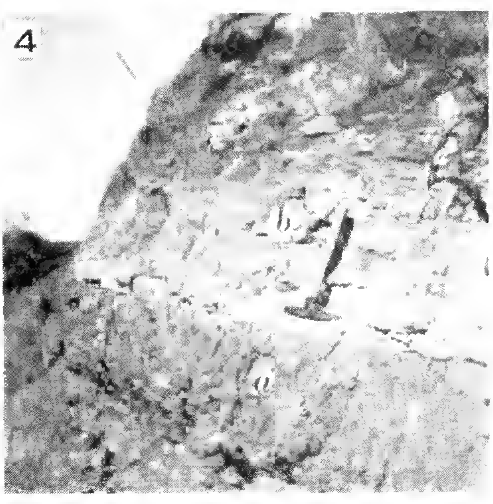

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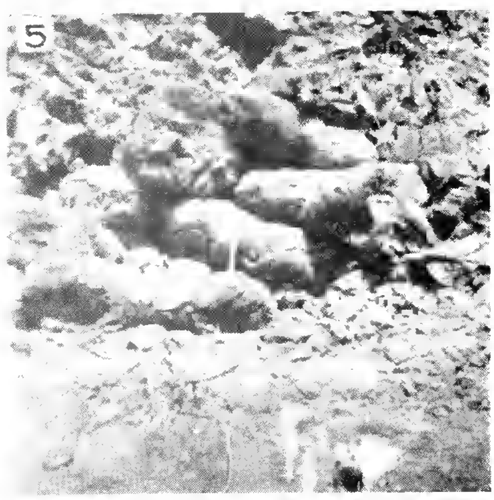

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POTENTIAL EVAPOTRANSPIRATION: A SIMPLIFICATION OF THORNTHWAITE'S METHOD

By A. A. Wilcock, B.Sc., B.Ed.

[Read 11 May 1950]

Abstract

It is shown that, where mean monthly temperatures do not fall below freezing point, the results which are obtained by Thornthwaite's method for calculating Potential Evapotranspiration may be exactly reproduced by a simple graphical method.

Introduction

The data available on the various climatic elements show very great differences in the density of the observing net-work and in the length of record. For only a few elements can the observations be regarded as reasonably complete. If the results of detailed special studies are to be extended beyond the area originally examined this can usually be done only if empirical formulae can be established which relate them to elements for which wide-spread observations are available. It is evident that the validity of such formulae outside the area for which they were devised can never be assumed.

Thornthwaite (1944, 1948) has proposed an empirical method for computing from temperature records the potential evapotranspiration, defined as 'the water-loss that would occur if soil moisture were constantly at the optimum level for plant growth.' As originally published the method offered to water-supply engineers and agriculturists empirical equations which fitted the observed water-loss in various American localities where water-need was fully met. In 1948 Thornthwaite gave his method a more general significance by proposing that potential evapotranspiration should be used as an essential element in a world classification of climate promising escape from many of the logical difficulties of earlier classifications.

It is therefore desirable that the method should be fully tested outside the area for which it was devised. One approach is for ecologists, engineers and others concerned with water-need to examine the extent to which the results obtained by Thornthwaite's method are consistent with their own observations. Unfortunately, as Thornthwaite is the first to admit, the method proposed for computing potential evapotranspiration is clumsy. The awkwardness of the method impedes theoretical discussion of its implications and involves the danger that workers who might contribute to its practical testing may be discouraged from doing so.

The aim of the present paper is to show that, under Australian conditions, the results which Thornthwaite's method give may be obtained far more simply. Throughout the discussion the aim is to reproduce the results obtained by the application of the original formulae. Since Thornthwaite claims only that his method gives values which are 'approximately correct' he presumably regards it as a matter of arithmetical convenience that he quotes results to hundredths of an inch or, in one table (1948, fig. 13) to hundredths of a centimeter. For the same reason figures are given in the present paper to an 'accuracy' which can have no physical significance.

Thornthwaite's Method

(The following discussion follows Thornthwaite in writing *PE* for potential evapotranspiration.)

Three steps are required:

(1) Determine for the station the annual heat index *I*, by summing 12 monthly heat indexes $i = (t/5)^{1.514}$, where $t°$ C is the mean monthly temperature.

(2) Use *I* to determine the slope of a straight line on a plot of log *PE* against log *t* (Thornthwaite 1948, fig. 13). This is drawn to pass through the appropriate point on an *I* scale on the graph, actually the point at which $t = (I/10)°$ C and $PE = 1{\cdot}6$ cm., and the 'point of convergence' at which $t = 26{\cdot}5°$ C and $PE = 13{\cdot}5$ cm. Read from the graph the value of *PE* corresponding to the monthly values of *t*. (The same result may be obtained from the equations given (Thornthwaite 1946, 1948), but these equations are obviously derived from straight lines fitted to plotted values of log *PE* against log *t*. The graphical form of the calculation is thus the original form though it was published later.)

(3) Multiply the unadjusted values of *PE* obtained in Step 2 by a factor (tabulated in Thornthwaite 1948, Table IV) to adjust for differences in the length of months and for seasonal changes in duration of daylight.

In the present paper the *PE-t* relationship has been replotted for a range of values of *I*. The use of linear scales on the axes loses the advantages of the straight lines of the log-log graph but probably gives a clearer view of the relationship between *PE* and *t*. The curves, drawn for values of $I = 30, 40, \ldots\ldots 120$, are closely enough spaced to permit accurate interpolation of those corresponding to intermediate values of *I*.

Simplification

It is evident that the calculations can be simplified only if a way can be found to avoid the computation of *I*. If it can be shown that *I* may be determined with sufficient accuracy from the annual mean temperature and range it becomes possible to add to the plotted curves (either the logarithmic or the linear version) a set of subsidiary curves which will permit the selection of the appropriate *PE-t* curve without a preliminary calculation of *I*.

It is clear that Thornthwaite's method, designed for climates where some or many months have temperatures below 0° C, must obtain *I* by summation, but under Australian conditions this may be avoided. Since any method of expressing *I* as a function of mean and range must involve assumptions about the form of annual temperature curves the ultimate justification of any such method must be empirical. The method used in arriving at the rule used here is thus an indication of line of approach rather than a proof and is presented in outline as an Appendix.

The formula proposed is:

$$I = i_m\,(12 + {\cdot}6\, r^2/m^2)$$

where $m°$ C = annual mean temperature,
$r°$ C = difference between mean temperature of hottest and coldest months,
and $i_m = (m/5)^{1.514}$ = i value for a temperature equal to annual mean.

The results of applying this formula have been compared with those obtained by summing 12 monthly values of *i* for many stations. Examples are given in Table 1. It will be seen that the differences are quite negligible even in the case of stations having up to three months below 0° C.

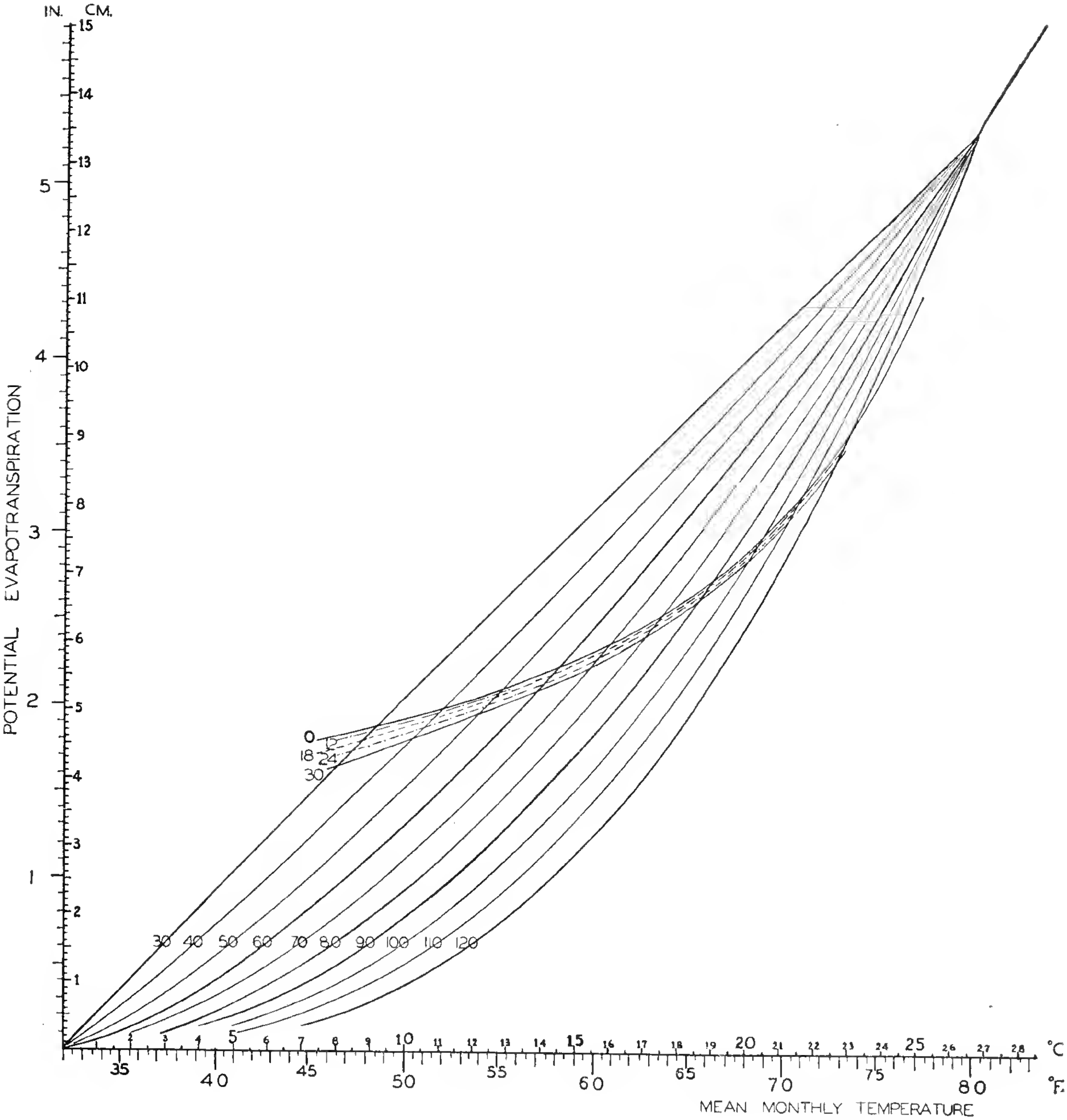

FIG. 1.—Graphs for obtaining Thornthwaite's values for unadjusted potential evapotranspiration. The curves numbered 30 . . . 120 give relationship of monthly temperature and monthly PE for selected values of annual heat index. The curves crossing them, numbered 0-30, give annual range of temp. in degrees F.

Determine annual mean temp. and range. Draw line perpendicular to temp. axis through annual mean temperature. The point at which this crosses the appropriate range curves lies on the *PE-t* graph for the station which may then be drawn with sufficient accuracy by interpolation between the *PE-t* curves provided. Read the unadjusted values of PE corresponding to the monthly mean temperatures.

C

TABLE 1

Station	m (°C)	r (°C)	I from rule	$I = \Sigma i$
Alice Springs	20·9	16·8	108·0	108·07
Brisbane	20·5	10·4	103·0	102·92
Perth	18·0	10·4	84·8	84·77
Sydney	17·3	10·4	103·0	102·92
Adelaide	17·2	12·2	79·8	79·96
Merbein	16·7	14·5	77·3	77·01
Melbourne	14·7	10·5	63·0	62·91
Hobart	12·4	9·0	48·8	48·66
Berlin	8·5	18·5	33·1	34·0
Pittsburgh	11·5	24·4	51·9	52·96
Omaha	10·1	31·1	50·5	52·8
Chicago	9·2	27·0	43·3	44·6

Using this formula it is possible to compute I and hence PE for a wide range of values of m and r. For example, when $m = 10°$ C the unadjusted values of PE corresponding to various ranges are:

Range	(degrees C)	0	3·3	6·7	10·0	13·3	16·7
	(degrees F)	0	6	12	18	24	30
PE	(cm.)	4·88	4·87	4·83	4·76	4·67	4·56

Using sufficient calculated values of this sort curves have been drawn crossing the PE-t curves. These are marked with the range (in degrees F) to which each corresponds and permit the selection or interpolation of the appropriate PE-t curve without the calculation of I. Thus if a station has an annual mean of 60° F and a range of 18° F the point at which the line $t = 60$ crosses the curve marked 18 lies on the PE-t graph for the station. This curve may be drawn in and the unadjusted value of PE corresponding to each monthly temperature may be read off. The value of I to which this curve corresponds need not be known but it can obviously be estimated by comparison with the curves given, whose I values are marked along the line $PE = 1·6$ cm.

The final step of adjusting PE values for variations in the duration of daylight is then necessary.

Conclusions

The purpose of the present paper is not to attempt an assessment of the results which Thornthwaite's method yields but to simplify the procedure so that interested workers may more easily examine the results.

Inspection of the results in simple graphical form suggests that much of the elaboration of calculation results only in differences too small to have any significance. The use of a complicated formula for I gives results which, especially at higher temperatures, do not differ significantly from those which would be obtained by simpler formulae.

Some of the more obvious criticisms of the method have been anticipated by Thornthwaite who holds that, unexpected as are some of the conclusions implied by the formulae, the facts of observation compel him to accept them. See, for instance, 1944, p. 698; 1948, p. 90. We are, however, entitled to inquire whether the facts of observation cover a range of conditions sufficiently wide to establish the general truth of the conclusions which follow from them. The basic assertion of the whole

method is that water-need may be computed from temperature figures alone. This is not a claim that temperature is the only factor involved, but does imply that the other factors which control water-need correlate so highly with temperature that their net effect can be forecast by a consideration of temperature alone. Whether this is true for any part of Australia remains to be proved, but it is easy to find examples in which Thornthwaite's formulae give results which suggest that the effect of humidity on water-need is not satisfactorily dealt with by using temperatures alone. Thus Merbein and Sydney in March should have, according to Thornthwaite's method, *PE* values of 9·2 and 9·3 cm. The tank evaporimeter readings are 15·5 and 8·9 cm. Admitting all the doubts about the interpretation of evaporimeter readings it is difficult to accept the Thornthwaite figures as nearer the truth about water-need at the two places.

Next, it seems reasonable to question how far we should apply Thornthwaite's method of using *PE* to calculate run-off. The potential evapotranspiration is, by definition, the water-loss which occurs by evaporation and transpiration when water is constantly available in optimum quantity. In humid areas and irrigation areas these conditions are met and the surplus for storage and run-off will be simply (water available − *PE*). The value of such a calculation when water available exceeds *PE* only occasionally is doubtful. The occasional presence of water in free supply cannot immediately call into being the same machinery of transpiration as was present in the areas for which the formula was devised. It seems unlikely that the very great success of Thornthwaite's methods in computing run-off in the Tennessee Valley will be repeated when they are applied to catchments in open, dry sclerophyll forest.

Finally, the Australian geographer will be particularly interested in the proposal to make computed values of *PE* basic to a world classification of climate. It would appear that the method faces a logical difficulty which will be serious in much of Australia. The only temperatures available for the calculation of *PE* are those observed under existing conditions, viz. with water in free supply for a few months only and with sparse vegetative cover. The computed values of water-need will therefore not be what they would be if water-need were fully met and the temperatures were modified as a result.

Acknowledgment

I acknowledge with thanks the assistance I have received in discussions with Associate Professor G. W. Leeper.

Appendix

Write mean monthly temp. $t = m + d$.

Where m°C is mean annual temperature

d°C (+ ve or — ve) is departure from mean.

Monthly heat index $i = (t/5)^{1.514}$

$= m/5^{1.514}(1 + d/m)^{1.514}$

First factor $= i_m$, monthly heat index for a month with a mean temperature equal to annual mean.

Where $d < m$ (i.e. no month has a mean temperature below freezing point) second factor may be expanded as a convergent series

$$i = i_m(1 + 1.514\ d/m + \cdot 39(d/m)^2 - \cdot 063\ (d/m)^3 \ldots .)$$

Annual heat index $I = \Sigma i$

From definition of mean $\Sigma d/m = 0$

$$I = i_m(12 + \cdot 39\,\Sigma(d/m)^2 \ldots .)$$

Σd^2 varies with the form of the temperature curve. The simplest analytical curve with the same general form as the usual annual temperature curve is the sine curve. Departures from this have been studied, for instance, by Köppen but not all differences affect Σd^2.

For a temperature curve which is sinusoidal

$\Sigma d^2 = 1 \cdot 5 \ \Sigma r^2$

where r°C is difference between temperatures of hottest and coldest months.

Suggested rule is thus:

$I = i_m(12 + \cdot 6 \ r^2/m^2)$

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3

REVISION OF McCOY'S 'PRODROMUS' TYPES FROM THE LILYDALE AND KILLARA DISTRICTS OF VICTORIA

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[Read 13 July 1950]

Summary

Early in the scientific history of Victoria, McCoy described Lower Devonian fossils from the Lilydale and Killara districts, and these are now revised. With most of them only changes of nomenclature are required, but McCoy's type specimens of *Pentamerus australis* prove to be referable to the genera *Meristella* and *Conchidium*.

Introduction

Professor Sir Frederick McCoy made a classic contribution to the palaeontology of Victoria in the early days of this State by preparing a series of works entitled 'Prodromus of the Palaeontology of Victoria, or Figures and Descriptions of Victorian Organic Remains.' Seven of the ten proposed decades appeared, being published by the Geological Survey of Victoria between the years 1874 and 1882 inclusive.

In connection with the study of the palaeontology of the Lilydale and Killara districts, east of Melbourne, it has become necessary to review McCoy's early work, and the results are listed in the following table:

Names in 'Prodromus'	Present Nomenclature
Spirigerina reticularis (Linnaeus)	*Atrypa reticularis* (Linnaeus) var.
Leptaena (Leptagonia) rhomboidalis (Wilckens)	*Leptaena rhomboidalis* (Wilckens) var.
Lichas australis (McCoy)	*Acanthopyge australis* (McCoy)
Orthoceras lineare (Münster)	Orthoceracone indet.
Pentamerus australis (McCoy)	*Meristella australis* (McCoy) *Conchidium* sp.
Phacops (Portlockia) fecundus Barrande	*Phacops* sp. nov.
Spirifera sulcata (Hisinger)	*Cyrtinopsis* cf. *cooperi* Gill

Stratigraphy

McCoy considered all these forms to be 'Upper Silurian' in age, which term at that time was equivalent to what is now called Silurian, the 'Lower Silurian' then being the present Ordovician. The Lilydale fossil *Atrypa reticularis* and the two Killara fossils *Lichas australis* and *Orthoceras lineare* were referred simply to the Upper Silurian (=Silurian). *Pentamerus australis* and *Phacops fecundus* were referred to the May Hill (= Llandovery) and *Spirifera sulcata* and *Leptaena rhomboidalis* to the Wenlock. All these forms are now regarded as being of Yeringian (Lower Devonian) age.

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Palaeontology

BRACHIOPODA

Genus **Meristella** Hall 1860

Cooper (1944) defined this genus as 'Small to large, smooth, biconvex usually with dorsal fold; oval in outline; rostrate, with circular foramen; ventral interior with dental plates and deeply impressed muscular area forming a trapezoidal or triangular pit; hinge plate divided, supported by a strong median septum and forming a small sub-rostral chamber; jugum similar to *Merista*. U. Sil. to Mid. Dev.'

McCoy's *Pentamerus australis* fits this generic description and is comparable with the shells figured by Hall. McCoy's species is not referable to the genus *Pentamerus* because it does not possess a 'ventral valve with long spondylium duplex; dorsal valve with two long subparallel plates supporting long curved brachial processes' (op. cit.). McCoy looked upon *P. australis* as 'an Australian representative of the European and American *P. oblongus* of exactly the same geological horizon at the base of the Upper Silurian, which it strongly resembles in size, shape, and surface.' Etheridge (1892), when writing on the Pentameridae of N.S.W., accepted this view, and referred fossils described by Mitchell as *P. oblongus* from N.S.W. to this species, and also stated that specimens described by Jenkins as *P. oblongus* probably belonged to it. Gurich (1901) also accepted these interpretations. The name *Pentamerus australis* has appeared in numerous lists, e.g. McCoy 1867, Basedow 1909, Chapman 1914, Brown 1941.

Meristella australis (McCoy)

Plate II, figs. 1, 2, 7, 8.

Pentamerus australis McCoy, 1877, p.p. 28-29, Pl. 47, figs. 9, 9*a*, 11, 12, *non* 10.
? *P. australis* Etheridge, 1892, pp. 50-52.

Type material. 1. Lectoholotype consisting of the steinkern of a ventral valve in a siltstone covered with iron oxide (N.M.V.* 12243) from 'section 12, Parish of Yering, Victoria.' For map and description of locality see Gill 1940. McCoy figured this specimen from two positions (figs. 9, 9a).

2. Lectoparatype. McCoy's fig. 11 is also a steinkern of a ventral valve in a similar matrix and from the same locality (N.M.V. 12242). The specimen is slightly compressed laterally.

3. Lectohypotype.† McCoy's fig. 12 is a very poor steinkern of perhaps a ventral valve. As the specimen is so inadequate and adds nothing fundamental to the description of the species, only the standing of a hypotype is suggested for it (N.M.V. 12241). McCoy's figure is a reconstruction not showing the breaks and imperfections of the specimen, so much so that his drawing looks like an exterior.

Descriptions. 1. Lectoholotype ventral valve sub-circular in outline, greatest width 43 mm. and greatest length the same. These measurements are taken in plan, i.e. not following the contours of the valve. Valve moderately and evenly convex, the median longitudinal profile rising about 13 mm. above the plane joining the anterior and posterior margins. Anterior margin non-plicate. Beak projects about 4 mm. beyond the posterior margin; erect. Interior of valve has large rostral cavity and deeply excavated muscle area. The dental plates are lost by the thickening of

* N.M.V.= National Museum of Victoria registered number.

† The terms *lectoholotype, lectoparatype,* and *lectohypotype* are used in a parallel sense to Singleton's (1945) *tectoholotype, tectoparatype,* and *tectohypotype.*

the shell on each side of the rostral cavity, but the steinkern shows that they were 5 mm. high. The somewhat heart-shaped rostral cavity between these plates is about 11 mm. wide at widest, and about 13 mm. long. The muscle field anterior to this has a pointed posterior end, and reaches anteriorly a point about 32 mm. from the umbo. It is widest anteriorly, where its width is 8 mm. This ventral valve of *Meristella* was mistaken by the original describer for a dorsal valve of *Pentamerus*.

2. Lectoparatype ventral valve is crushed, but nevertheless suggests a more ovate outline than that of the holotype. It is a valve from a younger animal, as shown by its lack of secondary thickening and its smaller size. Length in plan about 35 mm.; the width of the valve before crushing is estimated to be about 30 mm. in plan. This steinkern suggests that the exterior of the valve was smooth except for growth lines. Beak erect. Sides of delthyrium (see Plate II, fig. 8) constitute an angle of 90°. Dental plates 6·5 mm. long. Rostral cavity and muscle field as in holotype, but not so deeply excavated.

Comment. As was the custom at the time of description, no distinctions were made by McCoy between the type specimens. Following the more recent practice of basing a species fundamentally on a single holotype as far as possible, one is selected above. Specimen 12243 was apparently regarded as the chief specimen by McCoy because he drew two figures of it. This steinkern is of a fully mature or old age shell, the lectoparatype (12242) being the stage of development more commonly found.

Meristella australis is fairly common in the Upper Yeringian strata at Lilydale, being noted from Hull Road, Lilydale (loc. 1), Wilson's (loc. 2), Flowerfield Quarry (loc. 4), Flowerfield Cutting (loc. 5), Melbourne Hill, Lilydale (loc. 7), Hull Road, Mooroolbark (loc. 13), and from Chapman's Killara collection (loc. 34 or 35). The species is limited to fine siltstones, and does not occur as far as is known in the intercalated sandy horizons. It is common to find an association of smooth shells with fine sediments.

Meristella australis is nearest *M. bellensis* from the Bell Shale (Gill and Banks 1950) of the Zeehan area, West Tasmania (Gill 1950b), which is of Lower Devonian age. Both species have affinities with *M. nasuta* of North America (Hall 1867). No dorsal valve good enough for figuring has been found yet, but the structures are similar to those of *M. bellensis,* except that the muscle field is a little different in shape and not so strongly excavated. A related form has also been noted in the author's collection from Baton River, New Zealand (*vide* Shirley 1938). Mansuy (1916) has described *Meristella miareensis* from Indochina.

Genus **Conchidium** Hisinger 1799

Conchidium sp.

Plate II, fig. 9.

Pentamerus australis McCoy, 1877, Pl. 47, fig. 10.

Comment. McCoy misinterpreted this fossil, which is a steinkern of a ventral valve of *Conchidium* (N.M.V. 12244), preserved in a reddish siltstone from Yering, Victoria (loc. 4). A related species, *Conchidium polymitum*, has recently been described from the beds at Sandy's Creek, Gippsland (Gill 1949b), and the occurrence of *Conchidium* at Lilydale and Killara in Victoria, and on the Baton River in New Zealand noted.

Genus **Cyrtinopsis** Scupin 1896

Shirley (1938) and the writer (Gill 1942) have referred to this genus brachiopods from New Zealand and Victoria respectively, naming them *C. perlamellosa*

(Hall). Cooper has noted that *Delthyris* develops a spondylium-like structure secondarily, thus simulating *Cyrtinopsis*, and that Hall's species belongs to *Delthyris* and not *Cyrtinopsis* (Cooper 1944). In a recent paper (Gill 1950a) the Victorian form was re-named *Cyrtinopsis cooperi*, and it is probable that the New Zealand specimens are referable to this species. In both cases the fossils appear to be comparatively rare.

Cyrtinopsis cf. cooperi Gill

Spirifera sulcata McCoy, 1877, Pl. 46, figs. 9, 9a, 9b, 10, 10a.

Comment. The two specimens figured by McCoy are N.M.V. 12257 (which is fig. 9) and N.M.V. 12256 (which is fig. 10). In both cases the figures are reversed and somewhat idealized. Both are from 'Yering, Victoria,' and like his specimens of *Atrypa reticularis*, retain much of the calcic material of the original shell. This is unusual in the rocks of the Lilydale District, and the precise locality from which they came is unknown.

McCoy's specimens are comparable with *Cyrtinopsis cooperi*, but their internal structures are unknown, and the detail of the external morphology of *C. cooperi* has not yet been ascertained owing to rarity of material.

Fragments of *Cyrtinopsis* probably belonging to *C. cooperi* have been found in collections from Wilson's, Lilydale (loc. 2), Kilsyth (loc. 29), and from Taylor Road, Mooroolbark (a new locality at Mr. W. Widdows' home, 6 chains east of Hull Road and 72 feet north of Taylor Road). The holotype comes from the nearby locality (13) of Hull Road, Mooroolbark.

Genus Atrypa Dalman 1828

Atrypa reticularis (Linnaeus) var.

Spirigerina reticularis McCoy, 1877, pp. 25-26, Pl. 47, figs. 1, 1a, 1b, 1c, 2.

Comment. McCoy's specimens are recorded as coming from 'Yering, Victoria,' and the original calcic material of the shells is preserved. The matrix (as shown by the material between the valves) is a siltstone, and so the specimens do not come from the Cave Hill limestone. In any case, the locality would then be called Lilydale and not Yering. No fossil locality at present known has such a type of preservation, and so for the present, anyway, the precise stratigraphical position cannot be ascertained.

The specimen with the two valves (McCoy's figs. 1, *a-c*) is N.M.V. 12258, and the ventral valve showing the muscle impressions (McCoy's fig. 2) is N.M.V. 12259. The latter was a frail valve without matrix attached, and it was broken when transported with other types to a place of safe keeping during the war.

Kozlowski (1929) and the Fentons (1930, 1932, 1935) have made helpful studies of *Atrypa*. Poulsen (1943) proposed a new classification of the Atrypidae, but supposed that *Atrypa* s.s. possessed a dorsal median septum, which is not the case. Alexander (1949) has made a clear study of the genotype, and shown that with a study of evolutional series *Atrypa reticularis* can have stratigraphical significance. Dr. Alexander described English varieties and stated that in Poland and Sweden there appear to be forms of stratigraphical significance. She points out, too, that American forms on the whole show a more vigorous and extravagant development than European forms.

A number of specimens in Victoria have been given variety names, or referred to European and American species, but the need is really for a study of the whole group instead of isolated individuals, thus arriving at the delineation of an evolutional series.

Genus **Leptaena** Dalman 1828

Leptaeana rhomboidalis (Wilckens) var.

Leptaena (Leptagonia) rhomboidalis McCoy, 1877, pp. 19-20, Pl. 46, fig. 1.
Leptaena rhomboidalis Hill, 1942, pp. 40-41, Pl. 5, figs. 3, 8.

McCoy's specimen appears to be a smaller individual of the variety described by the author in 1942 from Hull Road, Mooroolbark (loc. 13). This sub-quadrilateral form is characteristic of the upper beds of the Yering Group, and differs from that found in the lower beds such as at Ruddock's Quarry (loc. 20), although the facies is very similar. Singleton (1945, pp. 252-253) listed this form.

CEPHALOPODA

Orthoceracone indet.

Orthoceras lineare McCoy, 1879, p. 28, Pl. 57, fig. 6.

Comment. This specimen (N.M.V.12128) was submitted to Dr. C. Teichert, who kindly informs me that on account of the absence of any internal structures it is not possible to provide even a generic name for this fossil. However, if forms are found at the same locality with such structures, it may then be possible to discover the taxonomic standing of the specimen figured by McCoy.

TRILOBITA

Genus **Acanthopyge** Corda 1847

When describing *Lichas australis,* McCoy (1876, p. 19) stated that 'this species belongs to that very restricted section of *Lichas* named *Acanthopyge* by Hawle and Corda, in which the head seems greatly simplified from the absence of the middle and posterior segmental furrows, leaving only one segmental lobe on each side of the glabella.' McCoy compared *Lichas australis* with Barrande's *Lichas haueri.*

Gürich (1901) established the subgenus *Euarges* with *Lichas (Euarges) haueri* as genotype. The Richters (1917) accepted this nomenclature for the genotype, and Reed (1923) discussed *Euarges* as a subgenus, but in 1932 the Richters re-established Corda's *Acanthopyge,* and used it as a generic name, apparently concluding that Gray's use of *Acanthopyga* in 1838 did not invalidate it. Bouçek (1933) used *Acanthopyge* as a subgeneric name throughout his paper except on page 4, where he heads a description '*Lichas (Ceratarges) pragensis,* n. sp.' with a footnote reading 'Synonymum of subgenus: *Euarges* Gür.' This is difficult to follow. Phleger (1936) used *Euarges* as a generic name and emended Gürich's subfamily of Euarginae. As Fletcher (1950) notes, he included Australia in the range of *Euarges,* and so must have regarded *Lichas australis* as belonging to that genus. Phleger (1936, 1937a, b) studied the whole Lichadid family, suggesting a new classification and establishing the superfamily Lichadaceae, but Warburg (1937, footnote pp. 213-214) is not pleased with it. Fletcher (1950) referred McCoy's species to *Euarges.*

Acanthopyge australis (McCoy)

Plate II, figs. 3-6.

Lichas australis McCoy, 1876, pp. 18-19, Pl. 22, figs. 11a, b.
Acanthopyge australis Etheridge and Mitchell, 1917, pp. 503-504.
Lichas australis Gill, 1939, pp. 140-142, Pl. 5, figs. 1-2.
Acanthopyge australis Gill, 1948, pp. 14-17.

Type material. 1. Lectoholotype consisting of the steinkern of a cranidium preserved in brownish siltstone (N.M.V. 7490) from 'Junction of Woori Yallock and Yarra,' Victoria. For precise locality see Gill 1945, p. 184 and fig. 2. McCoy

figured two specimens under the same figure number 11. The more complete specimen is the higher and the more enlarged on his plate 22, and this is now selected as the holotype. For ease of reference it will be called fig. 11a and the lower, less enlarged figure, 11b.

2. Lectoparatype consisting of the steinkern of a part of a cranidium preserved in the same matrix and from the same locality (N.M.V. 7489).

3. Hyptoype A. Steinkern of an almost complete carapace figured by the writer (1939, Pl. 5, fig. 1) and derived from grey siltstone with brown (oxidized) patches, from Syme's Quarry (loc. 35), Killara, Victoria (N.M.V. 14087).

4. Hypotype B. Steinkern of an incomplete cephalon showing eye pedicel, in the same matrix, from Syme's Tunnel, Killara (loc. 34), figured in Gill 1939, Pl. 5, fig. 2.

Descriptions. 1. Lectoholotype cranidium 8 mm. long in plan, and from the midline to the outer edge of the right fixed cheek along the posterior margin of the cephalon is 6 mm., so the complete cranidium must have had a maximum width of approximately 12 mm. The cranidium is very inflated, the middle of the glabella being 4 mm. higher than the anterior margin. The lobes are like those in *A. haueri* (Barrande), but as McCoy noted, the segmental lobes are narrower. The preglabellar furrow is more pronounced in *A. australis* (as shown in Pl. 11, fig. 3) than in *A. haueri.* Other cephalic differences were noted earlier (Gill 1939, pp. 142-143).

2. Hypotype A. In addition to the earlier observations on this specimen, it is noted that each segment of the thorax possesses anteriorly a narrow dorsally curved edge, which catches under the accommodating posterior edge of the segment in front of it. There are also locking mechanisms at the distal ends of the pleurae where the spines commence. There are two or three tubercles on each pleuron.

The pygidium possesses a doublure about 1 mm. wide, which has on it about four raised lines (imprinted in the matrix as fine furrows), more or less evenly spaced, and running parallel to the pygidial margin.

Comment. Acanthopyge australis (McCoy) is closely comparable with *A. haueri* (Barrande), which has been described from both Europe (Richters 1917) and Asia (Weber 1932). McCoy's species has been listed from localities in the Killara and Lilydale Districts (Gill 1938, 1939), and to these is now added that of Melbourne Hill, Lilydale (loc. 7), where a young specimen has been found (N.M.V. 14849). *A. australis* is listed as a typical fossil by Basedow (1909) and Chapman (1914).

Genus **Phacops** Emmrich 1839

Shimer and Shrock (1949) epitomize this genus as being characterized by 'Glabella more or less swollen; subcranial furrow continuous; genal angles generally rounded; marginal rim narrow; cephalic doublure slightly convex.' The genotype is *P. latifrons* Bronn. A closely allied genus is *Reedops,* which has the 'subcranial furrow absent in front; eyes small, well forward; otherwise like *Phacops*' (op. cit.). The genotype is *P. bronni* Barrande. *Phacops* occurs occasionally in the Silurian but has its maximum development in the Devonian. *Reedops* is a Lower Devonian genus.

McCoy's species lies between these two genera in that the subcranial furrow is almost obliterated or is absent anteriorly, and the eyes have migrated well forward, but are still large as in *Phacops,* and not small as in *Reedops.* A comparison can thus be made with *Reedops deckeri* (Delo 1935), which Delo referred to *Reedops* with some reserve (see also Delo 1940, p. 25). In Victoria there is a series of

Lower Devonian Phacopid trilobites which have been given mostly the names of species in the Upper Silurian of N.S.W. These are under review at present, and it appears that in most cases these names do not hold. The specimen referred to *Phacops crosslei* (Chapman 1915, Pl. 15, fig. 14, N.M.V. 12679) does not belong even to that genus. That referred to *P. serratus* (op. cit. Pl. 15, fig. 16, N.M.V. 2304) has most of the cephalon missing, and so is difficult to determine accurately. Some years ago, through the courtesy of Mr. H. O. Fletcher, Curator of Fossils, I looked through the phacopid specimens in the Australian Museum, Sydney, and came to the conclusion that the forms found in the Lilydale and Killara Districts of Victoria do not occur in the Yass-Bowning District of N.S.W. so far as present collecting shows.

Phacops sp. nov.

Phacops (Portlockia) fecundus McCoy, 1876, pp. 15-16.

Pl. 22, figs. 8-9, Pl. 23, figs. 1-6.

Comment. In 1895 Etheridge and Mitchell described as *Phacops sweeti* fossils collected by Mr. George Sweet from the Mansfield District of Victoria, and thought they were the same species as McCoy's *Phacops fecundus* described in the *Prodromus,* but they were not sure. They noted that McCoy's form was different from Barrande's *P. fecundus.* Basedow, apparently in error, recorded *P. fecundus* from N.S.W. (1909, p. 321). In 1939 the writer distinguished between *P. sweeti* and the *P. fecundus* of McCoy on the number of lenses in the eyes—an important morphological feature in this group (R. and E. Richter 1933, Størmer 1949)—and has confirmed this by examining McCoy's types, viz.

Plate 23, fig. 1	N.M.V.	12116
fig. 2		12117
fig. 3		12118
fig. 4		12119
fig. 5		12120.

It should be noted that McCoy's drawings are slightly reconstructed and show the specimens as being better preserved than they really are. For this reason it is desirable that any new species concerned should be established on other than the above material. The matrix at the locality from which McCoy's specimens came does not lend itself to good preservation. Only specimen N.M.V. 12116 (McCoy's Pl. 23, fig. 1) is well enough preserved to allow a count to be made of the lenses of the eyes. Fig. 2 (N.M.V. 12117) may be a different species from fig. 1. The specimens figured in McCoy's Pl. 22, figs. 8-9 have not been located in the Museum. In 1948 (p. 14) the writer pointed out that McCoy's *Phacops fecundus* is not referable to Barrande's Bohemian species, and in 1949 described some phacopid hypostomes, including one apparently belonging to the same species as McCoy's specimens. Fletcher (1950) has recently commented on the genus *Phacops* in Australia, and described a new species from the Lower Silurian of New South Wales.

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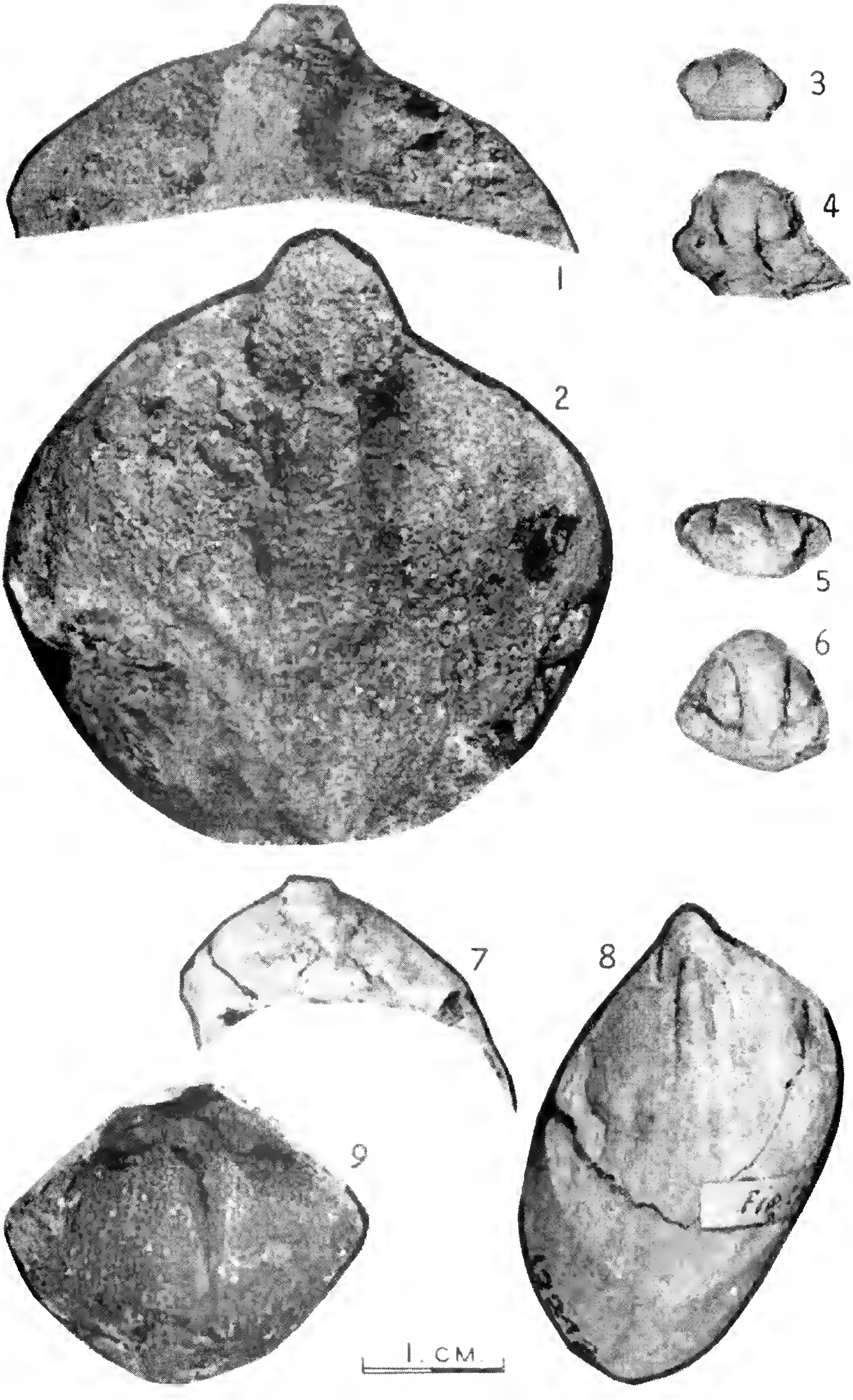
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Description of Plate II

Figs. 1-2.—*Meristella australis* (McCoy), LECTOHOLOTYPE, N.M.V. 12243, × 2.
Figs. 3-4.—*Acanthopyge australis* (McCoy), LECTOHOLOTYPE, N.M.V. 7490, × 2.
Figs. 5-6.—*A. Australis* (McCoy), LECTOPARATYPE, N.M.V. 7489, × 2.
Figs. 7-8.—*Meristella australis* (McCoy), LECTOHOLOTYPE, N.M.V. 12241, × 2.
Fig. 9.—*Conchidium* sp., figured by McCoy, N.M.V. 12244, × 2.

The author is indebted to Mr. L. A. Baillot of the Melbourne Technical College for the above photographs.

4

A CATALOGUE OF THE AUSTRALIAN TERTIARY FLORA

By Suzanne L. Duigan, M.Sc.

(Communicated by Professor J. S. Turner)

[Read 13 July 1950]

Introduction

During the course of a study of various Tertiary plant remains, the need has been felt for a comprehensive catalogue of previous records of the Australian flora of this period. A number of such catalogues is in existence—Etheridge (41), Ettingshausen (42, 43), and Johnston (57, 64, 65)—but unfortunately they are now completely out of date. More recent lists of fossils have been drawn up by Sussmilch (110) and Paterson (94), but they are restricted to Victorian genera.

General information regarding the Tertiary flora of Australia and the location of records is available in papers by Walcott (113), Chapman (14), Sussmilch (110), and Singleton (105). Details of certain groups of plants are given by Card and Dun (9), Florin (47), Maiden (75), Chapman (18), and Cookson and Duigan (30).

In the present catalogue, species are listed with the localities at which they have been found, and a note is made of the papers in which the original descriptions occur. The International Rules of Botanical Nomenclature have been followed as far as possible when deciding upon the validity of publication of species. However, as the list is designed to provide information regarding descriptions and illustrations of the flora as a whole, some records are included which do not completely satisfy the requirements of the Rules. Many diatoms have been recorded without descriptions, illustrations or authorities, but as they have been given the names of living species, and as the material upon which the identifications have been based is very similar to that used in the determination of present day species, they have been allowed to stand.

In order that the catalogue should be complete, a second list is given of suggested identifications, which are extremely tentative or are unsupported by descriptions and illustrations. Many of these appear in papers otherwise entirely divorced from palaeobotany, and consequently some may have been overlooked. The author would be grateful for notice of any omissions, which could then be incorporated in subsequent accounts.

Arrangement of the Catalogue

The Angiosperms have been catalogued according to the system of Engler and Prantl (40), but families and genera have been arranged alphabetically in order to facilitate reference. Fritsch (48, 49) has been followed for the classification of Algae, Ainsworth and Bisby (1) for Fungi, Copeland (115) for Pteridophyta and Florin (116) for Gymnosperms.

A number on the left of a species name refers to the paper, as indexed in the bibliography, in which the first record of this species appears. Letters associated

with these numbers show the type of material on which the identifications are based—

F. Fruit, Cone or Seed.
I. Macroscopic Portion of Flower.
L. Leaf.
P. Pollen Grain or Spore.
W. Wood.

Letters on the right of species names indicate the localities (as shown in the table below) from which the fossils have been recorded. When a number precedes one of these letters, it refers to a paper in which a record subsequent to the original one appears. '?' is used to denote any uncertainty as to whether a fossil really belongs to a given species.

In cases where the name of a species has been changed, a note of the alteration and the number of the paper in which it appears is placed after the original name. All information regarding localities, etc., is given under the new name, which is recorded independently. When any change has only been tentatively made, the suggested change is placed in brackets after the original name, and is not catalogued separately. The possible affinities of plants of uncertain systematic position are indicated in a similar manner, except in cases where the affinity is implied in the name.

List of Localities from which Fossils have been Recorded

TASMANIA

TA. Beaconsfield
TB. Brandy Creek
TC. Breadalbane
TD. Burnie
TE. Carnelian Bay
TF. Cora Lynn
TG. Derby
TH. Derwent River
TI. Geilston
TJ. Glenora
TK. Henty River
TL. Hobart
TM. King Island
TN. Launceston
TO. Macquarie Harbour
TP. Mt. Bischoff
TQ. New Norfolk
TR. One Tree Point
TS. Risdon
TT. Sandy Bay
TU. Stevenson's Bend
TV. Table Cape
TW. Windmill
TX. Woody Hill
TY. Locality Unspecified

VICTORIA

VA. Altona
VB. Anglesea
VC. Bacchus Marsh
VD. Balcombe Bay
VE. Ballarat
VF. Beenak
VG. Berwick
VH. Bogong High Plains
VI. Boolara
VJ. Bruthen
VK. Budgeree
VL. Bulla
VM. Chiltern
VN. Clifton Hill
VO. Cobungra River
VP. Creswick
VQ. Dargo High Plains
VR. Dargo River
VS. Darlimurla
VT. Daylesford
VU. Eganstown
VV. Eldorado
VW. Foster
VX. Gisborne
VY. Haddon
VZ. Hazelwood
Va. Hoddle's Creek
Vb. Keilor
Vc. Korumburra
Vd. Lake McRorie
Ve. Lal Lal
Vf. Lilicur
Vg. Lilydale
Vh. Limestone Reserve
Vi. Mallacoota Inlet
Vj. Malmsbury
Vk. Maryvale
Vl. Mornington
Vm. Morwell
Vn. Narracan
Vo. Nintingbool
Vp. Ouyen
Vq. Parwan
Vr. Pascoe Vale
Vs. Pitfield
Vt. Redruth
Vu. Sentinel Rock
Vv. Smythe's Creek
Vw. South Yarra
Vx. Stony Creek
Vy. Tanjil River
Vz. Thorpdale
Va'. Traralgon
Vb'. Wensleydale
Vc'. Yallourn

NEW SOUTH WALES

NA. Bannister
NB. Beneree
NC. Berridale
ND. Bungonia
NE. Cooma
NF. Dalton
NG. Darling Plains
NH. Elsmore
NI. Gulgong
NJ. Kiandra
NK. Newstead
NL. Orange
NM. Richmond River
Nm. Rock River
NN. Tingha
NO. Ulladulla

NP. Vegetable Creek (Emmaville)
NQ. Warrumbungle Mts.
NR. Wingello

QUEENSLAND

Qa. Brisbane
QA. Chinchilla
QB. Darra
QC. Duaringa
QD. Mt. Meerschaum
QE. Oxley
QF. Oxley Creek
QG. Sherwood
QH. South Pine River
QI. Strathpine
QJ. Warner
QK. Wolston

SOUTH AUSTRALIA

SA. Adelaide Plains
SB. Aldinga
SC. Cootabarlow
SD. Elizabeth Mine
SE. Eyre Peninsula
SF. Lake Frome
SG. Lake Macdonnell
SH. Lake Torrens
SI. Moorlands
SJ. Mount Lofty Ranges
SK. Pidinga
SL. Tanunda
SM. William Springs
SN. Wyeculuna
SO. Yorke Peninsula

WESTERN AUSTRALIA

WA. Albany
WB. Cape Riche
WC. Mount Elder Range

Records of Australian Tertiary Plants

ALGAE

BACILLARIOPHYCEAE

Centrales

24. *Actinocyclus Barklyi* Coates, Vw.
24. *A. duodenarius,* Vw.
106. *Attheya* sp., NE.
4. *Campylodiscus bicostatus,* Vw.
24. *C. clypeus,* Vw.
24. *C. cribrosus,* Vw.
24. *C. Hodgsonii,* Vw.
24. *C. parvulus,* Vw.
4. *Chaetoceros* sp. (?), Vd.
24. *Coscinodiscus eccentricus,* Vw.
24. *C. radiatus,* Vw.
106. *C. subconcavus* Grum., NE.
106. *C. Wittianus* Pant., NE.
24. *Cyclotella rectangula,* Vw.
24. *Hyalodiscus subtilis,* Vw.
24. *Hydrosera triquetra,* Vw.
106. *Melosira granulata* (Ehr.) Ralfs, NE.
106. var. *angustissima* O. Mull., NE.
106. *M. sulcata* (Ehr.) Kutz, NE.
106. *M. undulata* (Ehr.) Kutz var. *spiralis* Skv., NE.
24. *M.* sp., Vw.
9. *M.* spp., NM, NQ.
24. *Orthosira marina,* Vw.

Pennales

24. *Achnanthes brevipes,* Vw.
24. *A. subsessilis,* Vw.
4. *Cocconeis placentula,* Vd.
24. *C.* sp., Vw.
24. *Cocconema lanceolatum,* Vw.
24. *Cymbella* sp., Vw.
4. *Diatomella Balfouriana,* Vd.
4. *Diploneis elliptica,* Vd.
4. *D. major,* Vd.
4. *Epithemia gibba,* Vd.
24. *E. turgida,* Vw.
24. *E. Westernannii,* Vw.
4. *E. zebra,* Vd.
106. *Eunotia valida* Hust., NE.
24. *Gomphonema cymbiforme,* Vw.
4. *G. gracile,* Vw.
24. *G. lanceolatum,* Vw.
106. *G. longiceps* Ehr. var. *subclavata* Grun. (?), NE.
4. *Hantzschia amphioxys,* Vd.
24. *Himantidium arcut,* Vw.
24. *H. bidens,* Vw.
24. *H. gracile,* Vw.
24. *H. undulatum,* Vw.
24. *Navicula Amphisbaena,* Vw.
4. *N. cuspidata,* Vd.
24. *N. elliptica,* Vw.
4. *N. lauta,* Vd.
24. *N. minitula,* Vw.
24. *N. ovalis,* Vw.
24. *N. pusilla,* Vw.
4. *N. radiosa* var *tenella,* Vd.
24. *N. tumens,* Vw.
73. *N.* sp. (possibly Pleistocene), Vf.
72. *N.* sp., VE.
24. *Nitzschia* sp., Vw.
24. *Pinnularia acuminata,* Vw.
24. *P. distans,* Vw.
4. *P. distinguenda,* Vd.
4. *P. divergens,* Vd.
24. *P. major,* Vw.
24. *P. nobilis,* Vw.
24. *P. stauroneiformis,* Vw.
72. *P. viridis* (Nitz.) Ehr., VE.
106. var. *intermedia* Cleve (?), NE.
73. *P.* sp. (possibly Pleistocene), Vf.
24. *Pleurosigma balticum,* Vw.
24. *P.* spp., Vw.
24. *Stauroneis acuta,* Vw.
106. *S.* (*Pleurostauron*) *Playfairiana* Skvort, NE.
24. *S. pulchella,* Vw.
4. *Surirella Kerguelensis,* Vd.
4. *S. splendida,* Vw.
24. *S. striatula,* Vw.
4. *Synedra ulna,* Vd.
24. *S.* spp., Vw.
73. *S.* sp. (possibly Pleistocene), VE.
24. *Tabellaria* sp., Vw.
24. *Tryblionella gracilis,* Vw.
24. *T. marginata,* Vw.

CHLOROPHYCEAE

Cladophorales

Cladophoraceae

15. *Cladophora richmondiensis* Chap. (possibly Pleistocene), NM.

RHODOPHYCEAE

Cryptonemiales

Coralinaceae

31. *Lithophyllum hydractinoides* Crespin, Vb.

31. *Lithothamnion amphiroaeformis* Roth., Vb.

12. *L. ramosissimum* Reuss., Vp, 31Vb.

11. *L.* sp., TM.

ALGAE INCERTAE SEDIS

39. *Palaeachlya perforans* Duncan, TY.

11. *P. tuberosa* Chap., TM.

FUNGI

ASCOMYCETES

Hemisphaeriales

Micropeltaceae

28. *Plochmopeltinites Masoni* Cookson, Va', NJ.

Microthyriaceae

28. *Asterothyrites delicatissimus* Cookson, Vc'.

28. *A. minutus* Cookson, Vc', NJ.

28. *A. ostiolatus* Cookson, Vc', ?Vu.

28. *A. sinuatus* Cookson, Vc', VZ.

28. *Euthyrites oleinites* Cookson, Vc', VZ.

28. *Microthyriacites fimbriatus,* Cookson, Va'.

28. *M. grandis* Cookson, Va'.

28. *M.* sp. Cookson, Vc'.

28. *Notothyrites airensis* Cookson, Vu.

28. *N. setiferous* Cookson, NJ, NP.

Trichopeltaceae

28. *Trichopeltinites pulcher* Cookson, Vc', VZ.

PTERIDOPHYTA

EQUISITINEAE

65.L. *Calamites Hobartensis* R. M. Johnst., TR.

FILICINEAE

Filicales

Blechnaceae

55.L. *Lomaria primaeva* R. M. Johnst., TN, TU.

Hymenophyllaceae

55.L. *Trichomanides Tasmanica* R. M. Johnst., TC, TN, TU.

Marsileaceae

104.L. *Marsilea* sp. (?) Shirley (possibly Cretaceous), QC.

Osmundaceae

68.L. *Osmundia Tasmanica* R. M. Johnst., TK.

Pteridiaceae

45.L. *Acrostichum primordiale* Ett., QE.

34.L. *Pteris abbreviata* Deane, NH.

62.L. *P.* (?) *Belli* R. M. Johnst., TV.

65.L. *P. esculentiformis* R. M. Johnst., TN.

42.L. *P. Humei* Ett., NF.

43.L. *P. Torresii* Ett., NP.

Schizaeaceae

43.L. *Lygodium Strzeleckii* Ett. (68 *Osmunda*), NP.

GYMNOSPERMAE

CONIFERALES

Araucariaceae

43.L,F. *Agathis intermedia* (Ett.) Chapman and Crespin 23, 38Vm, NP, ?23WB.

119.L. *Araucaria balcombensis* Selling, VD.

119.L. *A. derwentensis* Selling, TL.

119.L. *A. Fletcheri* Selling, Nm.

65.L. *A. imbricatiformis* R. M. Johnst., TO.

89b.F,L. *A. Johnstoni* F.v.M. (47. L. Podocarpaceae), TI.

65.L. *Brachyphyllum* sp. R. M. Johnst., TR.

92.W. *Dadoxylon* sp. Nobes, Vc'.

43.L. *Dammara intermedia* Ett. = 23. *Agathis intermedia* (Ett.) Chapman & Crespin.

43.L. *D. podozamioides* Ett., NP.

Cupressaceae

43.L. *Callitris prisca* Ett., NP.

20.L. *C.* sp. Chap., SB.

16.W. ? *C.* sp. Chap., Vm.

2.W. *Cupressinoxylon Hookeri* Arber (47. Podocarpaceae), TQ.

92.W. *C.* sp. Nobes = 74. *Podocarpoxylon totara* Evans.

117.L. *Spondylostrobus Smythii* F.v.M., TA, ? 65 TN.

90.W. = 74. *Podocarpoxylon australe* Krausel.

82.F. = 102a. Dicotyledon.

45.F,L. *Thuites Wilkinsoni* Ett. (47. *Callitris*), QE.

Pinaceae

Podocarpaceae

43.F,L. *Pseudopinus Wilkinsoni* Ett. = 119. *Podocarpus Wilkinsoni* (Ett.) Selling.

43.L. *Dacrydium cupressinoides* Ett., NN, NP.

43.L. *Ginkgocladus australiensis* Ett. (47. *Phyllocladus*), NP.

43.L. *Heterocladiscos thujoides* Ett., NP.
100.W. *Mesembrioxylon fluviale* Sahni = 74. *Phyllocladoxylon fluviale* (Sahni) Krausel.
100.W. *M. fusiforme* Sahni = 74. *Phyllocladoxylon fusiforme* (Sahni) Krausel.
2.W. ? *M. Hookeri* (Arber) Seward 102c. = 74. *Cupressinoxylon Hookeri* Arber.
51.W. *M. Muelleri* (Schenk) Seward 102c. = 74. *Phyllocladoxylon Muelleri* (Schenk) Goth.
92.W. *M.* sp.A. Moorlands Nobes = 74. *Podocarpoxylon totara* Evans.
92.W. *M.* sp.B. Moorlands Nobes, SI.
92.W. *M.* sp.B. Yallourn Nobes = 74. *Podocarpoxylon australe* Krausel.
92.W. *M.* sp.B. Yallourn Nobes = 74. *Phyllocladoxylon Muelleri* (Schenk) Goth.
43.L. *Palaeocladus cuneiformis* Ett. (47. *Phyllocladus*), NP.
100.W. *Phyllocladoxylon fluviale* (Sahni) Krausel 74, QA.
100.W. *P. fusiforme* (Sahni) Krausel 74, QA.
102b.W. *P. Muelleri* (Schenk) Goth. 51, VY.
43.L,F. *Phyllocladus asplenioides* Ett., NP.
38.L. *P. Morwellensis* Deane, Vm.
102b.W. *P. Muelleri* Schenk = 51. *Phyllocladoxylon Muelleri* (Schenk) Goth.
35.L. *P. simplex* Deane, Vu.
90.W. *Podocarpoxlyon australe* Krausel 74, Vy, 92Vc'.
90.W. *P. Smythii* (F.v.M.) Kubart 74a. = 74. *P. australe* Krausel.
92.W. *P. totara* Evans, Vc'.
119.L. *Podocarpus Brownii* Selling, TD.
43.L,F. *P. praecupressina* Ett., NP, 32NR, 94Vn.
43.F,L. *P. Wilkinsoni* (Ett.) Selling 119, NN, NP.
119.L. *P.* sp. Selling, TD.
119.L. *P.* sp. Selling, Qa.

Taxaceae

65.L. *Athrotaxis* (?) *tamarensis* R. M. Johnst., TV.
45.L,F. *Glyptostrobus australis* Ett., QE.
43.L,F. *Sequoia australiansis* Ett. (47. L. *Podocarpus*, F. *Arthrotaxis*), NN, NP.
65.F. *S.* (?) *Tasmanica* R. M. Johnst. (47. *Arthrotaxis*), TI.
65.L. *Taxites Diemenensis* R. M. Johnst., TV.
61.L. *T. Thureaui* R. M. Johnst., TP.

CONIFERALES INCERTAE SEDIS

45.F. *Aulacolepis rhomboidalis* Ett., QE.
65.L. *Walchia* (?) *tasmanica* R. M. Johnst., TV.

CYCADALES

43.L. *Anomozamites Muelleri* Ett., NP.
101.W. *Cycadites Dowlingi* Scott (possibly Mesozoic), TN.
60.L. *C. microphylla* R. M. Johnst. (47. Podocarpaceae), TP.

GINKGOALES

38.L. *Ginko* sp. Deane, Vm.

ANGIOSPERMAE

MONOCOTYLEDONAE

Cyperaceae

45.L. *Cyperacites ambiguus* Ett., QG.

Gramineae

43.L. *Bambusites arthrostylinus* Ett., NP.
65.L. *Phragmites* (?) *calamiformis* R. M. Johnst., TO.
65.L. *P.* (?) sp. R.M. Johnst., TN.
43.L. *Poacites australis* Ett., NP.
20.L. *P.* sp. Chap., SB.

Palmae

45.L. Sp. Ett., QE.

Potamogetonaceae

45.L. *Zosterites angustifolius* Ett., QE.

DICOTYLEDONAE

Aceraceae

43.L. *Acer subintegrilobum* Ett. (20. *Sterculia*.), NK.
43.L. *Acer subproductum* Ett. (20. *Sterculia*.), NK, NP.
65.L. *A. Tasmaniensis* R. M. Johnst., TJ.

Apocynaceae

43.F. *Apocynocarpum sulcatum* Ett., NP.
33.L. *Apocynophyllum Berwickense* Deane, VG.
43.L. *A. crassum* Ett., NP.
42.L. *A. Etheridgei* Ett., NF.
43.L. *A. Kingii* Ett., NP.
43.L. *A. Mackinlayi* Ett. = 22. *Flindersia Mackinlayi* (Ett.) Chap.
42.L. *A. microphyllum* Ett., TE.
42.L. *A. travertinum* Ett., TE.
43.L. *A. Warburtoni* Ett., QN.
45.L. *A. Warraghianum* Ett., QB.
42.L. *Echitonium obscurum* Ett., TL.
36.L. *Lyonsiaephyllum Duni* Deane, NQ.
42.L. *Tabernaemontana primigenia* Ett., NF.

Aquifoliaceae

43.L. *Ilex Macleayana* Ett., NP.

Araliaceae

43.L. *Aralia elsmoriana* Ett., NK.
43.L. *A. Freelingii* Ett., NP.

43.L. *A. Oxleyi* Ett. (20. *Sterculia*), NP.
43.L. *A. prisca* Ett. (20. *Sterculia*), NP.
42.L. *A. subformosa* Ett., QE.
33.L. *Panacites Howitti* Deane, Vs.

Betulaceae

32.L. *Alnites latifolia* Deane, NR.
42.L,F. *Alnus Maccoyi* Ett., NP, NK.
42.L. *A. Muelleri* Ett., TE, TS.
42.L. *Betula daltoniana* Ett., NF.
42.L. *B. derwentensis* Ett., TE.
54.L. *B. Launcestonensis* R. M. Johnst., TN.
65.L. *B. punctata* R. M. Johnst., TJ.

Bombaceae

42.L. *Bombax Mitchelli* Ett. = 22. *Endiandra Mitchelli* (Ett.) Chap.
42.L. *B. Sturtii* Ett., NF, 23WB.

Boraginaceae

42.L. *Cordia tasmanica* Ett., TS, 93Vr.

Casuarinaceae

43.L. *Casuarina Cookii* Ett., NP.
45.L. *C. primaeva* Ett., QE.
97.F. *C.* sp. Patton, Vh.
94.L. *C.* sp. Paterson, Vn.

Celastraceae

42.L. *Celastrophyllum Cunninghami* Ett. = 43. *Celastrus Cunninghami* Ett.
42.L. *Celastrus Cunninghami* Ett., NF..
43.L. *C. Lefroyi* Ett., NP.
43.L. *C. praeclaenus* Ett., NP.
43.L. *C. praeeuropaeus* Ett., NP.
45.L. *Elaeodendron priscum* Ett., QE.
43.L. *E. subdegener* Ett., NP.

Ceratophyllaceae

45.W,F. *Ceratophyllum australe* Ett., QE.

Combretaceae

43.L. *Getonites Wilkinsoni* Ett., NP.

Cunoniaceae

43.L. *Callicoma primaeva* Ett., NP.
43.L. *Ceratopetalum Gilesii* Ett., NP.
43.L. *C. Macdonaldi* Ett., NP.
42.L. *C. praearbutoides* Ett., TE.
45.L. *C. primigenium* Ett., QB.
42.L. *C. Woodii* Ett., TS.
19.L. ? *Weinmannia* sp. Chap., Vn.

Ebenaceae

45.F,L. *Diospyros cretacea* Ett., QB, QE.

Elaeocarpaceae

33.L. *Aristotelia* sp. (?) Deane, VG.
84.F. *Elaeocarpus angularis* (F.v.M.) Selling 119, VV, Vv, Vy.
42.F. *E. Bassii* Ett., TA.
83.F. *E. Clarkei* (F.v.M.) Selling 119, VV, Vv, 37Vw, NL, 7NI.
82.F. *E. Lynchii* (F.v.M.) Selling 119, VY, 37VW, 7NI.
43.F,L. *E. Muelleri* Ett., NK, NP.
20.L. *E. praeobovatus* Chap., SB.
83.F. *E. trachyclinis* (F.v.M.) Selling 119, VV, Vv, 7NI.

Ericaceae

45.L. *Andromeda australiensis* Ett., QE.

Eucryphiaceae

33.L. *Eucryphia Gregorii* Deane, Vs.

Fagaceae

42.L. *Castanopsis Benthami* Ett., NF.
43.L. *Dryophyllum Howitti* Ett., NP.
45.L. *D. Lesquereuxii* Ett., QE.
43.L,F. *Fagus Benthami* Ett. = 93. *Nothofagus Benthami* (Ett.) Paterson.
43.L. *F. celastrifolia* Ett., NP.
65.L. *F. Glenoraensis* R. M. Johnst., TJ.
43.L. *F. Hookeri* Ett., NP.
67.L. *F. Jonesii* R. M. Johnst., TK.
65.L. *F. Launcestonensis* R. M. Johnst., TN.
45.L. *F. leptoneura* Ett., QE.
33.L. *F. Luehmanni* Deane = 94. *Nothofagus Luehmanni* (Deane) Paterson.
33.L. *F. Maideni* Deane = 19. *Nothofagus Maideni* (Deane) Chap.
43.L. *F. Muelleri* Ett. = 94. *Nothofagus Muelleri* (Ett.) Paterson.
32.L. *F. Pittmani* Deane, NR.
45.L. *F. prae-ninnisiana* Ett., QB.
45.L. *F. prae-ulmifolia* Ett., QB, QF.
42.L. *F. risdoniana* Ett. = 22. *Nothofagus risdoniana* (Ett.) Chap.
42.L. *F. Wilkinsoni* Ett. = 93. *Nothofagus Wilkinsoni* (Ett.) Paterson.
33.L. *F.* sp. (?) Deane, VG.
65.L. *F.* sp. R. M. Johnst., TN.
43.L. *Nothofagus Benthami* (Ett.) Paterson 93., ?93Vr, NK, NP, 32NR.
33.L. *N. Luehmanni* (Deane) Paterson 94., VG, 94VS.
33.L. *N. Maideni* (Deane) Chap. 19, VG, 94Vn, ?19Vn, ?93Vr.
43.L. *N. Muelleri* (Ett.) Paterson 94, ?33VG, ?93VS, ?93Vr, NP.
42.L. *N. risdoniana* (Ett.) Chap. 22, TS, 22SO.
42.L. *N. Wilkinsoni* (Ett.) Paterson 93, 93Vr, NF, 22SN, 23WB.
22.L. *N.* aff. *Moorei* (F.v.M.) Maiden, SH.
26.P. *N.* sp.a. Cookson, VD, VF, Vc, Vk, NP, SI.

26.P. *N.* sp.b. Cookson, VB, VD, VF, VI, Vk, Vz, NP, SI.
26.P. *N.* sp.c. Cookson, VB, VD, VF, VI, Ve, Vq, Vz, NC, NP, SI.
26.P. *N.* sp.d. Cookson, VB, VD, VF, VK, Vk, Vq, Vz, NP, SI.
26.P. *N.* sp.e. Cookson, VA, VB, VD, VF, VI, Vq, Vk, Vz, Vc', NC, NJ, NP, SI.
26.P. *N.* sp.f. Cookson, VA, VB, VD, VI, VK, Vk, Vc', NP, SI.
26.P. *N.* sp.g. Cookson, VF, NP, SI.
26.P. *N.* sp.h. Cookson, VD, SI.
26.P. *N.* sp.i. Cookson, SI.
26.P. *N.* sp.j. Cookson, VA, VD, VF, VK, SI.
43.L. *Quercus Austini* Ett., NP.
60.L. *Q. Bischoffensis* R.M.Johnst., TP.
43.L. *Q. Blaimingii* Ett., NP.
45.L. *Q. colophylla* Ett., QE, QF.
43.L. *Q. Dampieri* Ett. (32.Sapindaceae), NP.
42.L. *Q. Darwinii* Ett., NF, NP, 43NK.
42.L. *Q. drymejoides* Ett., NF.
43.L. *Q. Edelii* Ett., NP.
45.L. *Q. eucalyptoides* Ett., QE.
43.L. *Q. Greyi* Ett., NP.
43.L. *Q. hapaloneuron* Ett., NP.
43.L. *Q. Hartogi* Ett., NP.
42.L. *Q. Hookeri* Ett., NF.
45.L. *Q. nelsonica* Ett., QE.
43.L. *Q. praephilippinenensis* Ett., NF.
45.L. *Q. pseudo-chlorophylla* Ett., QE.
45.L. *Q. rosmarinifolia* Ett., QE.
45.L. *Q. Stokesii* Ett., QE.
42.L. *Q. Tasmanii* Ett., TS, 65TN.
43.L. *Q. Wilkinsoni* Ett., NN, NP.
45.F. *Q.* sp. Ett., QE.

Lauraceae

45.L. *Cinnamomum Haastii* Ett., QB.
42.L. *C. hobartianum* Ett., TL.
42.L. *C. Leichhardti* Ett., NF, 43NK, 32NR.
43.L. *C. Nuytsii* Ett., NP.
80.L. *C. polymorphoides* McCoy, 61, 64 TO, 65TU, VC, 19Vn, 32Vs, 81VQ, 42NF, 43NP.
94.L. var. *crassa* Paterson, Vn.
80.L. var. *major* McCoy, VC.
38.L. *C. praevirens* Deane, Vm.
45.L. *C. primigenium* Ett., QE, ?103QB, ?103QE.
22.L. *C. Tatei* Chap., SM.
42.L. *C. Woodwardii* Ett., TL.
36.L. *Cryptocarya australis* Deane, ?94Vn, NQ.
36.L. *C. praeobovata* Deane, 94VS, NQ.
45.L. *Diemenia lancifolia* Ett., QE.
43.L. *D. perseaefolia* Ett., NK.
43.L. *D. speciosa* Ett., NK, NP.
42.L. *Endiandra Mitchelli* (Ett.) Chap 22, 22VC, 93Vr, NF, 23WB.
36.L. *E. praepubens* Deane, 22VC, NQ.
42.L. *Laurus australiensis* Ett., NF, 43NK, NP.
45.L. *L. plutonina* Ett., QB.
60.L. *L. Sprentii* R. M. Johnst., TP.
80.L. *L. Werribeensis* McCoy, VC, 81VQ.
32.L. *Litsaeophyllum wingellense* Deane, NR.
43.L. *Sassafras Lesquereuxii* Ett., NP.

Leguminosae

67.L. *Acacia Meiringii* R.M.Johnst., TK.
43.L. *Cassia castanospermoides* Ett., NP.
42.L. *C. Cookii* Ett., NF.
45.L. *C. Etheridgei* Ett., QE.
45.L. *C. Flindersi* Ett., TE.
43.L. *C. phaseolitoides* Ett., NP.
45.L. *C. prae-memnoniana* Ett., QB.
45.L. *C. prae-phaseolitoides* Ett., QB.
43.L. *Copaifera australiensis* Ett., NP.
42.L. *Dalbergia Diemenii* Ett., 65TJ, NF.
43.L. *Dalbergiophyllum affine* Ett., NP.
43.L. *Dolichites coriaceus* Ett., NP.
82.F. *Geoffroya McCoyi* (F.v.M.) Selling 119, VY, Vy, 7NI.
42.L. *Leguminosites Kennedyi* Ett., NF.
45.L. *L. pachyphyllus* Ett., QE.
45.L. *Podalyriophyllum brochidodromum* Ett., QE.
43.L. *Podogonium macrocarpum* Ett., NP.

Loganiaceae

94.F. *Strychnos* sp. Paterson, Vn.

Loranthaceae

43.L. *Loranthus Kennedyi* Ett., NP.

Magnoliaceae

32.L. *Drimys levifolia* Deane, ND.
36.L. *D.* sp. Deane, Vs.
42.L. *Magnolia Brownii* Ett., NF, 22SJ, 22SF.
93.L. *M. microphylla* Paterson, Vr.
42.L. *M. Torresi* Ett., NF.
104.L. *M.* sp. (?) Shirley (possibly Cretaceous), QC.

Malpighiaceae

43.L. *Banisteriophyllum australiense* Ett., NN, NP.
45.L. *B. cretaceum* Ett., QB.
43.L. *Malpighiastrum Babbagei Ett.*, NK.
45.L. *M. cretaceum* Ett., QB.

Meliaceae

32.L. *Cedrelophyllum antiqua* Deane, NR.

Menispermaceae

87.F. *Rhitidocaryon Wilkinsoni* F.v.M. (119), NB, NL, 119TA.

Monimiaceae

33.L. *Atherosperma Berwickense* Deane, VG.

33.L. *Daphnandra obliqua* Deane, VG.
33.L. *D. Selwyni* Deane, Vs.
33.L. *Hedycarya latifolia* Deane, VG, 94Vn, ?19Vn, 22SD.
43.L. *H. Wickhami* Ett., NP.
33.L. *Mollinedia helicioides* Deane, VG.
33.L. *M. Muelleri* Deane, Vs, ?19Vn.
33.L. *M. praelongipes* Deane, VG.
45.L. *Monimia prae-vestita* Ett., QE.
43.L. *M. vestita* Ett., NP.

Moraceae

43.L. *Artocarpidium Gregoryi* Ett., NK, NP.
45.L. *A. pseudo-cretaceum* Ett., QB.
43.L. *A. Stuartii* Ett. = 22. *Ficus Stuartii* (Ett.) Chap.
93.L. *Ficonium nitidum* Paterson, Vr.
42.L. *F. Solandri* Ett., 19Vn, NF, 20SB.
65.L. *F.* (?) *solandroides* R. M. Johnst., TO.
43.L. *Ficus Burkei* Ett., NP.
43.L. *F. Gidleyi* Ett., NP.
45.L. *F. Ipswichiana* Ett., QB.
43.L. *F. Phillipsii* Ett., NP.
43.L. *F. Solanderi* Ett., NP.
43.L. *F. Stuartii* (Ett.) Chap. 22, NP.
104.F. *F. subgoepperti* Shirley (possibly Cretaceous), QC.
103.L. *F. subsycamorus* Shirley, QE.
43.L. *F. Willsii* Ett., NP.
104.L. *F.* (?) sp. Shirley (possibly Cretaceous), QC.

Myricaceae

42.L. *Myrica Eyrei* Ett., TE.
43.L,F. *M. Konincki* Ett., NK, NP.
45.L. *M. pseudolignitum* Ett., QB, QE.
43.L. *M. pseudosalix* Ett. (36.*Myrsine*), NP, 36NQ.
103.L. *M. subsalicina* Shirley, QE.
45.L. *Myricophyllum longepetiolatum* Ett., QG.

Myrsinaceae

43.L. *Myrsine Stokesii* Ett., NP.

Myrtaceae

43.L. *Callistemophyllum Beckeri* Ett., NP.
43.L. *C. Hackii* Ett., NP.
43.L. *C. obliquum* Ett., NP.
43.L. *C. Swindeni* Ett., NP.
33.L. *Eucalyptus Chapmani* Deane 75, VG.
45.L. *E. cretacea* Ett., QB, QE.
45.L. *E. Davidsoni* Ett., QE.
42.L. *E. Delftii* Ett., NF.
43.L. *E. Diemenii* Ett., NP, 22SH.
43.L. *E. Hayi* Ett., NP.
33.L. *E. Hermani* Deane, VG.
43.L. *E. Houtmanni* Ett., ?33VG, NP, 22SM.
33.L. *E. Howitti* Deane, VG.
60.L. *E. Kayseri* R. M. Johnst., TP.
33.L. *E. Kitsoni* Deane, VG, 93Vr, 94VS, ?19Vn, 22SD, 22SH.
13.W. *E. melliodora* Cunn., VJ.
61.L. *E. Milligani* R. M. Johnst., TO.
43.L. *E. Mitchellii* Ett., 33VG, NP, 22SD.
33.L. *E. Muelleri* Deane = 75. *E. Suttoni* Deane.
45.L. *E. oxleyana* Ett., QE.
13.W. *E. piperita* Sm., Vi.
80.L. *E. Pluti* McCoy, VT.
33.L. *E. praecoriacea* Deane (95. ? *Eucalyptus*), Vl.
45.L. *E. scoliophylla* Ett., QE.
33.L. *E. Suttoni Deane* 75, VG.
45.L. *E. warraghiana* Ett., QB.
33.L. *E. Woollsii* Deane = 75. *E. Chapmani* Deane.
10.L. *E.* aff. *amygdalina* Labill, Vt.
95.L. *E.* sp. Patton, VL.
96.L. *E.* spp. Patton, Vx.
43.L. *Myrtonium lanceolatum* Ett., NP.
43.L. *M. obtusifolium* Ett., NP.
45.L. *Myrtophyllum latifolium* Ett., QE.
22.L. *Tristania praeconferta* Chap., SD.
38.L. *T.* sp. (?) Deane, Vm.
33.L. *Tristanites angustifolia* Deane, VG, 19Vn, 94Vn.
33.L. *T. Muelleri* Deane, VG, ?94Vn.

Oleaceae

43.L. *Olea Macintyrei* Ett., NP.
27.L. *Oleinites crenulata* Cookson, SI.
27.L. *O. Willisii* Cookson, VZ, Vc'.

Piperaceae

43.L. *Piper Feistmantlii* Ett., NK.

Pittosporaceae

33.L. *Pittosporum praeundulatum* Deane, Vs.
42.L. *P. priscum* Ett., NF.

Proteaceae

38.L. *Banksia adunca* Deane, Vm.
43.L. *B. Blaxlandi* Ett., NP.
43.L. *B. Campbelli* Ett., NP.
45.L. *B. crenata* Ett., QE.
45.L. *B. cretacea* Ett., QE.
38.L. *B. fastigata* Deane = 30. *Banksieaephyllum fastigatum* (Deane) Cookson and Duigan.
43.L. *B. Hovelli* Ett., NP.
43.L. *B. lancifolia* Ett., 61TJ, NP.
43.L. *B. Lawsoni* Ett., NP.
43.L. *B. myricaefolia* Ett., NP.
45.L. *B. plagioneura* Ett., QE.
43.L. *B. Poolii* Ett., NP.
22.L. *B. pracgrandis* Chap., SD.
45.L. *B. sub-longifolia* Ett., QE.
10.L. *B.* cf. *marginata* Cav., Vt.
30.F. *B.* sp. Cookson and Duigan, VV.

30.F. *B.* sp. Cookson and Duigan, Vc'.
65.W. *B.* sp. R. M. Johnst., TC.
29.P. *Banksieaeidites elongatus* Cookson, Vc'.
29.P. *B. minimus* Cookson, Vc'.
30.L. *Banksieaephyllum acuminatum* Cookson and Duigan, Vc'.
30.L. *B. angustum* Cookson and Duigan, Vc'.
38.L. *B. fastigatum* (Deane) Cookson and Duigan 30, Vc'.
30.L. *B. laeve* Cookson and Duigan, Vc'.
30.L. *B. obovatum* Cookson and Duigan, Vc'.
30.L. *B. pinnatum* Cookson and Duigan, Vc'.
29.P. *Beaupreaidites elegansiformis* Cookson, VC, Va, Vc', NP, SG, SI.
29.P. *B. verrucosus* Cookson, VC.
45.L. *Conospermites linearifolius* Ett., QE.
43.L. *Dryandra Benthami* Ett., NP.
43.L. *D. praeformosa* Ett., NP.
38.L. *D. urniformis* Deane, Vm.
42.L. *Dryandroides Johnstonii* Ett., TE.
34.L. *Grevillea darlingioides* Deane, NP.
45.L. *G. Oxleyana* Ett., QE.
43.L. *G. proxima* Ett., NP.
43.L. *G. Wentworthi* Ett., NP.
22.L. *Hakea ambigua* Meissn., SD.
43.L. *H. Duttoni* Ett., NP.
42.L. *Knightia daltoniana* Ett., NF.
33.L. *Lomatia Bosistoides* Deane, VG.
43.L. *L. Brownii* Ett., ?93Vr, 94Vn, NP, 32NR.
43.L. *L. castaneaefolia* Ett., NP.
33.L. *L. dubia* Deane, VG.
43.L. *L. Evansii* Ett., NP.
43.L. *L. Finnisii* Ett., NP.
43.L. *L. Goyderi* Ett., NP.
22.L. *L. Mawsoni* Chap., SE.
33.L. *L. obscura* Deane, VG.
33.L. *L. perspicua* Deane, VG, ?22SD.
42.L. *L. praelongifolia* Ett., TE, 38Vm.
33.L. *L. reticulata* Deane, VG, ?94Vn.
65.L. *L. ? Tasmanica* R. M. Johnst., TC.
35.L. *Persoonia cuneata* Deane, Vu, ?22SM.
43.L. *P. Murrayi* Ett., NP.
32.L. *P. propiqua* Deane, ND.
94.F. *P.* sp. Paterson, Vn.
29.P. *Proteacidites adenanthoides* Cookson, Vb', NP, SC.
29.P. *P. annularis* Cookson (*Lambertia, Xylomelum*), VC, VD, Va, Ve, Vb', Vc', NP, SC, SI.
29.P. *P. callosus* Cookson, SI.
29.P. *P. crassus* Cookson, VB, SC, SI.
29.P. *P. grandis* Cookson, Vb'.
29.P. *P. incurvatus* Cookson, VB, Vb', SI, SK.
29.P. *P. obscurus* Cookson, VD, Vc', SI.
29.P. *P. parvus,* Cookson, NP.
29.P. *P. rectomarginis* Cookson (*Petrophila*), VC.
29.P. *P. reticulatus* Cookson, SI.
29.P. *P. symphyonemoides* Cookson, VD, Vc'.
29.P. *P. truncatus* Cookson (*Isopogon*), Vc'.
29.P. *P. tuberculatus* Cookson, VC, Vc'.
45.L. *Proteoides australiensis* Ett, QE.
43.L. *Rhopala Parryi* Ett., NP.
43.L. *R. sapindifolia* Ett., NP.
45.L. *Rhopalophyllum australe* Ett., QB, QE.

Ranunculaceae

45.F. *Debeya affinis* Ett., QB, QE.
45.L. *D. australiensis* Ett., QB.

Rhamnaceae

43.L. *Pomaderris Banksii* Ett., NP, ?20SB.
42.L. *Pomaderrites Banksii* Ett., 93Vs, NF.

Rubiaceae

42.L. *Coprosma praecuspidifolia* Ett., TE.
35.L. *Coprosmaephyllum angustifolium* Deane, Vu.
35.L. *C. attenuatum* Deane, Vu.
22.L. *C. Edmondsi* Chap., SA.
36.L. *C. Kitsoni* Deane, NQ.
35.L. *C. minus* Deane, Vu.
35.L. *C. ovatum* Deane, Vu.
32.L. *Psychotriphyllum attenuatum* Deane, NR.

Rutaceae

43.L. *Boronia Harrisii* Ett., NP.
43.L. *B. Hookeri* Ett., NP.
42.L. *Flindersia Mackinlayi* (Ett.) Chap. 22, NP, 22SH.

Salicaceae

42.L. *Salix Cormickii* Ett., TL.

Santalaceae

43.L. *Santalum Frazeri* Ett., NP.

Sapindaceae

43.L. *Cupanites Selwyni* Ett., NK, NP.
33.L. *Nephelites Berwickense* Deane, VG.
32.L. *N. denticulata* Deane, ND.
32.L. *N. equidentata* Deane, NR.
32.L. *N. ovata* Deane, NR.
33.L. *N. quercifolia* Deane, VG.
33.L. *N. Ulrichi* Deane, Vs.
43.L. *Sapindus Gossei* Ett., NK, NP.
103.L. *S. Oxleyensis* Shirley, QE.
42.L. *S. tasmanicus* Ett., TH.

Sapotaceae

42.L. *Sapotacites achrasoides* Ett., TE.
43.L. *S. Forresti* Ett., NP.

43.L. *S. Huntii* Ett., NP.
42.L. *S. oligoneuris* Ett., TE, 62TV.

Saxifragaceae

32.L. *Argophyllites levis* Deane, NR.
33.L. *A. parvifolia* Deane, Vs.
36.L. *Anopterus Pittmani* Deane, NQ.
43.L. *Trachyphyllum myosotinum* Ett., NP.
43.L. *T. obtusum* Ett., NP.

Sterculiaceae

94.L. cf. *Brachychiton populneus* R.Br., Vn.
33.L. *Commersonia* sp. (?) Deane, VG.
19.L. *Sterculia Gippslandica* Chap., Vn, 94Vn, ?94VS.
19.L. *S. Hauschildti* Chap., Vn, ?20SB.
33.L. *S. Muelleri* Deane, Vs.
22.L. *S.* (?) Chap., NG.

Tiliaceae

32.L. *Corchorites crenulata* Deane, NR.
45.L. *Etheridgea subglobosa* Ett., QE.

Ulmaceae

43.L. *Ulmophyllum oblongum* Ett., NP.
60.L. *Ulmus Tasmanicus* R. M. Johnst., TP.

Verbenaceae

20.L. cf. *Clerodendron* sp. Chap., SB.
42.L. *Premna Drummondii* Ett., TE.

Species Incertae Sedis

88.F. *Acrocoila anodonta* F.v.M., NI.
33.F. *Carpolithes acaciaeformis* Deane, Vs.
43.F. *C. amaranthaceus* Ett., NK.
45.F. *C. complanatus* Ett., QE.
65.F. *C. coniferoides* R. M. Johnst., TU.
65.F. *C. Derwentensis* R. M. Johnst., TR.
45.F. *C. epacridoides* R. M. Johnst., QE.
45.F. *C. fagiformis* Ett., QE.
42.F. *C. gaertnerioides* Ett., TH.
64.F. *C.* (?) *Geissii* R. M. Johnst., TJ.
43.F. *C. morisoniaeformis* Ett., NK.
65.F. *C. Perrinii* R. M. Johnst., TO.
43.F. *C. pygeoides* Ett., NK.
42.F. *C. risdonianus* Ett., TS.
45.F. *C. semisulcatus* Ett., QE.
45.F. *C. siliculaeformis* Ett., QE.
65.F. *C. Strahanensis* R. M. Johnst., TO, ?33VC.
65.F. *C. ulmaciformis* R. M. Johnst., TC.
65.F. *C. ulmiformis* R. M. Johnst., TR.
43.F. *C. wetherellioides* Ett., NK.
82.F. *Celyphina McCoyi* F.v.M. = 119. *Geoffroya McCoyi* (F.v.M.) Selling.
90.F. *Conchocaryon Smithii* F.v.M. (Proteaceae), NI.
83.F. *Concotheca rotundata* F.v.M. (Proteaceae), 65TN, Vo.
84.F. *C. turgida* F.v.M. (Proteaceae 37. Sapindaceae), 59TA, 58TC, 63TA, 63TI, Vo, 37VW, 114Vy, 52SL.
84.F. *Dieune pluriovulata* F.v.M. (Capparidaceae, Pittosporaceae), VY, 7NI.
88.F. *Eisothecaryon semiseptatum* F.v.M. (Olacineae), NI.
88.F. *Illicites astrocarpa* F.v.M. (Magnoliaceae), NI.
89.F. *Liversidgea oxyspora* F.v.M. (Bixaceae, Capparidaceae, Guttiferae, Rutaceae), NM.
88.F. *Ochthodocaryon Wilkinsoni* F.v.M. (65. Capparidaceae), NI.
83.F. *Odontocaryon Macgregorii* F.v.M., Vo, 7NI.
100.W. *Pataloxylon porosum* Sahni, QK.
100.W. *P. scalariforme* Sahni, QD.
88.F. *Pentacoila Gulgongensis* F.v.M. (65. Sapindaceae), NI.
59.F. *Penteune Allportii* F.v.M. (119. *Elaeocarpus*), TI.
83.F. *P. brachyclinis* F.v.M. (Sapindaceae, Meliaceae, 119. *Elaeocarpus*), Vv, 7NI, 52SL.
83.F. *P. Clarkei* F.v.M. = 119. *Elaeocarpus Clarkei* (F.v.M.) Selling.
83.F. *P. trachyclinis* F.v.M. = 119. *Elaeocarpus trachyclinis* (F.v.M.) Selling.
65.L. *Phyllites aceriformis* R. M. Johnst., TN.
65.L. *P. acicularis* R. M. Johnst., TN.
45.L. *P. actinoneuron* Ett., QE.
65.L. *P. asteriformis* R. M. Johnst., TN.
65.L. *P. Atkinsoni* R. M. Johnst., TV.
65.L. *P. Belsteadii* R. M. Johnst., TV.
65.L. *P. Breadalbanensis* R. M. Johnst., TC.
65.L. *P. Buttonii* R. M. Johnst., T.C.
65.L. *P. cenarrheniformis* R. M. Johnst., TV.
65.L. *P. cuneatiformis* R. M. Johnst. (47. *Libocedrus*), TR.
42.L. *P. ficiformis* Ett., TE.
65.L. *P. Fraxiniformis* R. M. Johnst., TV.
33.L. *P. Gregorii* Deane (Proteaceae), VG.
42.L. *P. juglandiformis* Ett., TE.
65.L. *P. lanceolatus* R. M. Johnst., TJ.
42.L. *P. ligustroides* Ett., TE.
65.L. *P. Milligani* R. M. Johnst., TC.
42.L. *P. mimosaeformis* Ett., TE.
65.L. *P. myrtiformis* R. M. Johnst., TN.
68.L. *P. oleaciformis* R. M. Johnst., TJ.
65.L. *P. oreodaphnioides* R. M. Johnst., TN.
42.L. *P. phaseolites* Ett. (*Kennedya*), TE.

65.L. *P. pomaderriformis* R. M. Johnst., TJ.
42.L. *P. populiformis* Ett., TE.
65.L. *P. prae-populiformis* R. M. Johnst., TJ.
65.L. *P. proteaciformis* R. M. Johnst., TV.
42.L. *P. pyriformis* Ett., TE.
68.L. *P. salicifolium* R. M. Johnst., TJ.
65.L. *P. serratifolium* R. M. Johnst., TP.
42.L. *P. sophoraeformis* Ett., TE.
65.L. *P. Taylorii* R. M. Johnst., T.P.
65.L. *P. teliodentatus* R. M. Johnst., TJ.
65.L. *P. Waratahensis* R. M. Johnst., TP.
65.L. *P. Wintlei* R. M. Johnst., TN.
65.L. *P. Wynyardensis* R. M. Johnst., TV.
30.L. *P. yallournensis* Cookson and Duigan, Vc'.
84.F. *Phymatocaryon angulare* F.v.M. = 119. *Elaeocarpus angularis* (F.v.M.) Selling.
88.F. *P. bivalve* F.v.M., NI.
82.F. *P. Mackayi* F.v.M. (37. *Elaeocarpus*), VY, 37VW NL, 7NI, 52SL.
84.F. *Platycoila Sullivani* F.v.M. (Proteaceae), 58TA, Vo, Vy, 7NI.
88.F. *Pleiacron elachocarpum* F.v.M., NI.
118.F. *Pleioclinis Couchmanni* F.v.M. (Sapindaceae), VY, Vo.
83.F. *P. Shepherdi* F.v.M., Vo, ?65TC.
88.F. *Plesiocapparis leptocelyphis* F.v.M., (Capparidaceae), 59TE, 59TR, 63TA, 63TI, NI.
116.F. *P. megasperma* F.v.M., NI.
82.F. *P. prisca* F.v.M., VY, 7NI.
59.F. *Rhitidotheca Johnstonii* F.v.M. = 42. *Elaeocarpus Bassii* Ett.
82.F. *R. Lynchii* F.v.M. = 119. *Elaeocarpus Lynchii* (F.v.M.) Selling.
37.F. *R. major* Deane, VW.
83.F. *R. pleioclinis* F.v.M. = 118. *Pleioclinis Shepherdi* F.v.M.
42.F. *Sapindostrobus dubius* Ett., NP.
82.F. *Spondylostrobus Smythii* F.v.M. (*Callitris*, 74. Dicotyledon 119. Burseraceae), 56TB, 58TA, 58TC, VV, VY, Vy, NL, 7NI, 52SL.
82.F. *Trematocaryon McLellani* F.v.M. (Verbenaceae), VV, VY, 7NI.
117.F. *Tricoilocaryon Barnardi* F.v.M. (65. Sapindaceae 119. Burseraceae), NI.
27.P. *Tricolporites sphaerica* Cookson (Oleaceae), Vk.
29.P. *Triorites magnificus* Cookson, SI.
89a.F. *Wilkinsonia bilaminata* F.v.M. (Sapindaceae), NB, NI.
86.F. *Xylocaryon Lockii* F.v.M. (Olacineae), Vo.

Suggested Identity of Various Australian Tertiary Plants

ALGAE

BACILLARIOPHYCEAE

Pennales

106. *Cymbella* sp., NE.
106. *Fragilaria* sp., NE.
106. *Pinnularia* sp., NE.
106. *Synedra* sp., NE.

CHLOROPHYCEAE

Charales
Characeae

21. Sp. (possibly Pleistocene), WC.

Cladophorales
Cladophoraceae

21. *Cladophora* sp. (possibly Pleistocene), WC.

RHODOPHYCEAE

Cryptonemiales
Coralinaceae

12. *Lithophyllum* sp., Vp.
12. *Lithothamnion* aff. *lichenioides* Ellis and Solander, Vp.
12. *L.* sp., Vp.
11. *L.* sp., TM.

FUNGI

12. Boring Fungus indet., Vp.

PTERIDOPHYTA

FILICINEAE

25.P. Sp.

Filicales

35.L. Sp., Vu.
89.L. Sp., NM.

Polypodiaceae

96.L. *Polypodium pustulatum* Forst., Vx.

Pteridaceae

55.L. *Adiantum* sp., TT.
96.L. *Pteridium aquilinum* Kuhn, Vx.
112.L. *Pteris* sp., VT.

LYCOPODINEAE

54.L. *Lycopodium* sp., TM.

PTERIDOSPERMAE

81.L. *Taeniopteris tenuissima-striata* McCoy (47.*Eucalyptus*), VH, VQ.

GYMNOSPERMAE

98a.P. Sp., SK.

CONIFERALES

54.L. Sp., Vm.

Araucariaceae

33.L. *Dammara* sp., Vl.

Cupressaceae

53.W. Sp., VM, VP.

Pinaceae

55.W. *Pinus* sp., TF.
109.W. *P.* sp., TX.

Podocarpaceae

25.P. Sp.
96.W. *Dacrydium* sp., Vx.
14.W. *Mesembrioxylon* sp., VA.
96.W. *Phyllocladus* sp., Vx.
33.L. *Podocarpus* sp., Vl.

CYCADALES

11.F. Sp., Vm.

GINKGOALES

81.L. *Salisburia Murrayi* McCoy, VR.

ANGIOSPERMAE

MONOCOTYLEDONAE

10.L. Rush, Vu.
8.L. Sedge, QJ.

Cyperaceae

8.L. *Eleocharis* sp., QH.

DICOTYLEDONAE

Aceraceae

54.L. *Acer* sp., TN.
78.L. *A.* sp. (47. *Sterculia*), VC.

Apocynaceae

14.L. *Apocynophyllum* sp., Vl.

Casuarinaceae

16.W. *Casuarina* sp., Vn.
3.W. *C.* sp., VN.
35.L. *C.* sp., Vu.
25.P. *C.* sp.
98a.P. *C.* sp., SK.

Cunoniaceae

36.L. *Weinmannia* sp., NQ.

Euphorbiaceae

36.L. *Adriana* sp., NQ.

Fagaceae

61.L. *Fagus* sp., TP.
98.P. *Nothofagus* spp., SG.
98a.P. *N.* spp., SK.
50.L. *N.* sp., Vg.

Lauraceae

81.L. Sp., VO, VR.
50.W. *Beilschmiedia* sp., Vg.
55.L. *Cinnamomum* sp., TU.
33.L. *C.* sp., Vs.
93.L. *C.* sp., Vr.
61.L. *C.* sp., TP.
78.L. *C.* sp., VC.
54.L. *Laurus* sp., TN.
93.L. *L.* sp., Vr.
61.L. *L.* sp., TP.
78.L. *L.* sp., VC.
102a.W. *Prospectina Harti* Scott, TN.
102a.W. *P. Keltiei* Scott, TN.
102a.W. *P. Pasmorei* Scott, TN.

Leguminosae

46.W. *Acacia melanoxylon* R.Br., VT.
55.W. *A.* sp., VM, VP.
33.L. *A.* sp., Vl.
35.L. *A.* sp., Vu.
8.L. *A.* sp., QI.
113F,I. *Eutaxia empetrifolia* Schlech, VX.
35.L. *Mirbelia* sp., Vu.
35.L. *Pultenaea* sp., Vu.

Magnoliaceae

61.L. *Magnolia* sp., TP.

Meliaceae

36.L. *Amoora* sp., NQ.
36.L. *Owenia* sp., NQ.

Monimiaceae

33.L. *Daphnandra* sp., Vl.
36.L. *Mollinedia* sp., NQ.
14.L. *M.* sp., Vl.

Moraceae

81.L. *Ficus Dionysia* Mass., VQ.
36.L. *F.* sp., NQ.
35.L. *F.* sp., Vu.

Myoporaceae

33.L. *Myoporum* sp., Vs.

Myrsinaceae

35.L. *Myrsine* sp., Vu.

Myrtaceae

98a.P. Sp., SK.
8.L. *Callistemon* sp., QI.
77.L. *Eucalyptus obliqua* l'Herit, VY.
8.L. *E. propinqua* Deane and Maid., QH.
71.L. *E.* sp., VF.
33.L. *E.* sp., VL, Vl.
8.L. *E.* sp., QH.
75.L. *E.* sp., TD.
53.W. *E.* sp., VM, VP.
107.L. *E.* sp., VT, Vj.
8.L. *Melaleuca* sp., QI.
14.L. *Tristanites* sp., Vl.

Platanaceae

54.L. *Platanus* sp., TN.

Proteaceae

98.P. Sp., SG.
98a.P. Sp., SK.
99.F. *Banksia* sp., VP.

91.F. *B.* sp., VP.
107.F. *B.* sp., VM, VP.
108.F. *B.* sp., VT, Vj.
76.L. *B.* sp., SI.
55.W. *B.* sp., TF.
23.L. *Grevillea* sp., WA.
33.L. *Hakea* sp., Vl.
71.L. *Lomatia* sp., VF.
14.L. *L.* sp., Vl.
76.L. *Telopea* sp., SI.

Rubiaceae

36.L. *Randia* sp., NQ.

Rutaceae

36.L. *Flindersia* sp., NQ.

Sapindaceae

59.L. Sp., TT.
14.L. *Nephelites* sp., Vl.

Saxifragaceae

6.W. Sp., NO.

Solanaceae

55.L. *Solanum* sp., TT.

Sterculiaceae

36.L. *Commersonia* sp., NQ.
35.L. *Lasiopetalum* sp., Vu.

Symplocaceae

119.F. *Symplocus* sp., V.

Thymeliaceae

78.L. *Daphnogena* sp., VC.

Ulmaceae

54.L. *Ulmus* sp., TN.
55.W. *U.* sp., TF.

Verbenaceae

8.L. *Gmelina* sp., QI.

Vitaceae

36.L. *Vitis* sp., NQ.

SPECIES INCERTAE SEDIS

69.F. *Carpolithes* (*Plesiocapparis*) *Clarkii* R. M. Johnst., TG.
81.L. *Lastrea Dargoensis* McCoy, VH, VQ.

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5

FURTHER STUDIES IN CHONETIDAE (PALAEOZOIC BRACHIOPODA) FROM VICTORIA

By Edmund D. Gill, B.A., B.D.*

[Read 14 December 1950]

Summary

The *Chonetes robustus* gens is described and its evolution discussed. *Chonetes australis* McCoy is re-described with the help of some special preparations. New species are established, viz. *Chonetes micrus* and *Notanoplia loyolensis* from the Lower Devonian, and *Chonetes buchanensis* and *C. teicherti* from the Middle Devonian.

Introduction

Chonetidae occur only in Silurian and Devonian rocks in Victoria, as far as is known at present, but they exist in great numbers and variety, especially in the Devonian. The following is a list of described species, and there are still others waiting the collection of better material before description.

Upper Silurian	*Chonetes melbournensis* Chapman
Lower Devonian	*C. cresswelli* Chapman
	C. baragwanathi Gill
	C. bowieae Gill
	C. killarensis Gill
	C. micrus sp. nov.
	C. productoidus Gill
	C. psiloplius Gill
	C. robustus Chapman
	C. ruddockensis Gill
	C. taggertyensis Gill
	Notanoplia australis (Gill)
	N. loyolensis sp. nov.
	N. withersi (Gill)
Middle Devonian	*Chonetes australis* McCoy
	C. buchanensis sp. nov.
	C. gaskini Gill
	C. teicherti sp. nov.

The Victorian chonetids are comparable with those of Tasmania (Gill 1948, 1950a), New Zealand (Allan 1935, Shirley 1938, Gill 1950b), and Indochina (Mansuy 1916, 1919, 1921, Gill 1945).

Evolution

The Palaeozoic faunas of Victoria lived in geosynclinal seas, a tectonically mobile area where change was common and enormous thicknesses of sediments accumulated (Browne 1947). Even if the mutation rate were the same as elsewhere, the evolution rate was probably much higher by reason of the changing evironment.

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A well-adapted species shows little development in a constant evironment, whatever the mutation rate, but when the environment is fluid, new mutations are utilized, and so the rate of evolution goes up. The flux within the organism (genotypic change or mutation rate) is thus geared to the flux in the environment. It may be as well to state that by rate of evolution the writer means the speed of change in morphology.

Chonetes exhibits a monopodial type of evolution (cf. Small 1948).

Incidence of Species

In Silurian time, *Chonetes melbournensis* was prolific in this part of the Tasman geosyncline. This is the only species so far described from the Silurian rocks of Victoria, and there are traces of but few others. On the other hand, in Devonian time there was a comparatively sudden burst of evolution in Chonetids, yielding a whole galaxy of species. Fourteen species have been described, and there is material in hand proving the existence of others. In addition, three species of *Notanoplia* have been described.

Genetic Relationships

As the chonetid fauna is described, the genetic relationships of the species are becoming clearer. The chief hindrance is that many of the species are still inadequately known. The ventral valve only has been described in a number of cases, and the type of preservation often prevents the determination of small but important structures.

There is evidence to suggest that *C. taggertyensis* is related to the European *C. sarcinulatus*, and so it may be a migrant. On the other hand, there is a rich gens of apparently indigenous species related to *C. robustus*, and it is proposed that in future this group be known as the *C. robustus gens*. The term gens is employed in its original sense (Vaughan 1905) of 'the aggregate of all the species which possess, in common, a large number of essential properties, and are continuously related either in space or time' (cf. Fenton 1929, p. 502). Figure 1 indicates the

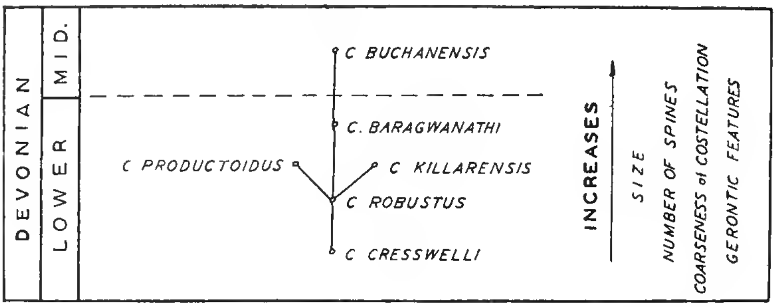

FIG. 1.—Age, composition and evolution of the *Chonetes robustus* gens.

probable relationships of the species in the *C. robustus* gens; the lines indicate relationships as now understood, and no significance is to be attached to the length of the lines. All the species occur in numbers except *C. killarensis* and *C. productoidus*, and it may be that these were offshoots from the main line of evolution that did not progress very well.

The gens of *C. robustus* comprises a group of larger, rather coarsely costellate species, with short ventral median septum, and spines set at right angles to the

hingeline. Where known, the dorsal valve has a comparatively long median septum and two accessory septa as described herein for *C. cresswelli* (Fig. 2). The body cavity is small, the shells being concavo-convex. Table 1 sets out some of the

TABLE I. *Table of features of species of the* Chonetes robustus *gens.*

SPECIES	Size in mm.	No. of spines	No. of costellae	No. of costellae per cm.	Median sinus	Gerontic features
C. buchanensis . .	25 x 20	?10	40	11	Absent	1, 2, 3
C. baragwanathi .	30 x 12	10	42	10	Present	1,2
C. killarensis . . .	20 x 17	10	37	16	Present	
C. productoidus . .	21 x 17	8	c.45	15	Absent	1
C. robustus . . .	19 x 12	8	c.40	15	Present	
C. cresswelli . . .	13 x 7·5	8	54	22	Present	

features of this group of species. 'Number of costellae' means how many occur along the anterior margin of the holotype ventral valve, and 'Costellae per cm.' means the number measured in a width of one centimetre across the middle of the holotype ventral valve of the species concerned. The gerontic features represented by numbers are—

1. Obesity.
2. Irregular growth lines (especially towards the anterior margin).
3. Irregularity of costellae (especially towards the anterior margin).

The development of gerontic features towards the anterior margin of the shell (i.e. the latest area of growth of the individual) while the younger parts of the shell have a more regular growth, appears to be a reflection of phylogeny in ontogeny. While one is aware of the well-based criticisms by de Beer and others of the classic Theory of Recapitulation, it appears to be true as Swinnerton says (1932, p. 333) that 'As applied to the individual character, the palaeontological evidence in support of this doctrine is overwhelming. . . The fundamental phenomenon is . . . parallelism (i.e. in ontogeny and phylogeny), for evolution is not an abstraction; it is a process which proceeds through the medium of developing individuals.'

In Table 1 the species are listed according to age, in that *C. buchanensis* is Middle Devonian, *C. baragwanathi* is late Lower Devonian (Gill 1949), and the other species earlier in the Lower Devonian. The table shows that there is an overall increase in size of shell, in the number of spines, in the number of costellae per centimetre of valve surface, and in the appearance of gerontic features. The outline of the shells, the presence or absence of a median sinus, and the shape of the spines appear to be merely specific characters, and not constant through the gens in any way. The median sinus disappears in the tumid members of the gens. It may be noted that the median sinus evolved independently a number of times in the Chonetidae.

Migration

Before being named as new species, the brachiopods described in this paper were compared with those described in literature. Many superficial comparisons were noted, but no intimate relationships. However, scientific comparison is difficult in many cases owing to limited knowledge of the species concerned.

It has been suggested that *a priori* we can assume that forms of marine life found in Australia, for instance, will be different from those found in Europe and North America, because of the great distances involved. However, taking the geological column as a whole, we cannot as a rule correlate fossil faunas which are less than a million years apart in age. If a form migrated 10,000 miles in 1,000,000 years, this would be an average of only 17·6 yards (about 15 metres) per year.

Distance therefore is not the barrier so much as the concomitants of distance—differences in temperature, depth, nature of sea-floor (where bottom-living forms are concerned), salinity, turbidity, and so on. It is not a matter of time and space so much as a problem of opportunity.

Thus the facies of a form probably has more to do with whether it may be expected to be widely dispersed or not, than any other factor. If an animal is pelagic, then it is much more likely to be widely distributed. If it has a limited habitat, e.g. a brachiopod limited to a muddy sea-floor of moderate depth, these very limitations will make it less likely to achieve distant migration.

Moreover, migration over long distances inevitably involves areas with a different range of ecological factors, and these will cause selection which tends to differentiate the animal from the parent stock. It would appear also that the same or similar mutations occur in different places, and so homoeomorphy is rife. General similarity of form thus does not necessarily mean genetic relationship.

One pictures the 'Victorian' chonetids making their way about the Tasman geosynclinal seas and perhaps into neighbouring waters, but whether they effected any more distant migrations has yet to be proved.

Systematic Descriptions

A. Lower Devonian Species.

Genus **Chonetes** Fischer de Waldheim 1837

Chonetes cresswelli Chapman

(Pl. III, fig. 5; Text fig. 2)

C. cresswelli Chapman, 1903, pp. 77-78, Pl. XII, fig. 7.
C. cresswelli Gill, 1945, pp. 134-135, Pl. VIII, fig. 5.

Type material. Holotype: A photograph of this specimen has not been published before, and so one is reproduced as Plate III, fig. 5. New is a Hypotype consisting of a dorsal valve preserved as a steinkern and external mould (N.M.V.* 14712, the counterparts being set in one block of plaster) in fawn micaceous siltstone from Lilydale (no doubt loc. 2), Victoria. Collected by Rev. A. W. Cresswell, after whom the species was originally named.

Description of Hypotype. Valve semicircular, being 1·4 mm. wide and 8 mm. long. Mildly concave. Cardinal angles approximately right angles. Hingeline straight, and palintrope linear. About 55 radial costellae. The area between the accessory septa on the interior of the valve is nearly smooth, and the costellae show through on the rest. Cardinal process small, divided by a median longitudinal groove. Continuous with it on each side is a plate (probably a crural base) about 1·75 mm. long and making an angle of about 25° with the hingeline. A median septum is present, scarcely traceable at the umbonal end but higher and rather plate-like further anteriorly; it then gradually fades out into the floor of the valve. The septum is fine and reaches at least 4 mm. from the hingeline, i.e. at least half the length of the valve. On each side of the median septum is an accessory septum about 2 mm. long which makes an angle of about 15° with it. These septa merge into the crural bases, and are aligned with the sides of the cardinal process (see Fig. 2).

Comment. A dorsal valve of this species has not been previously described. Its general plan is very similar to that of *Chonetes baragwanathi*, and provides further evidence of the compactness of the *C. robustus* gens.

* References in this paper to registered numbers in public fossil collections are given thus: N.M.V. = National Museum of Victoria; M.D.V. = Mines Department of Victoria (Geological Survey of earlier records); M.U.G.D. = Department of Geology, University of Melbourne.

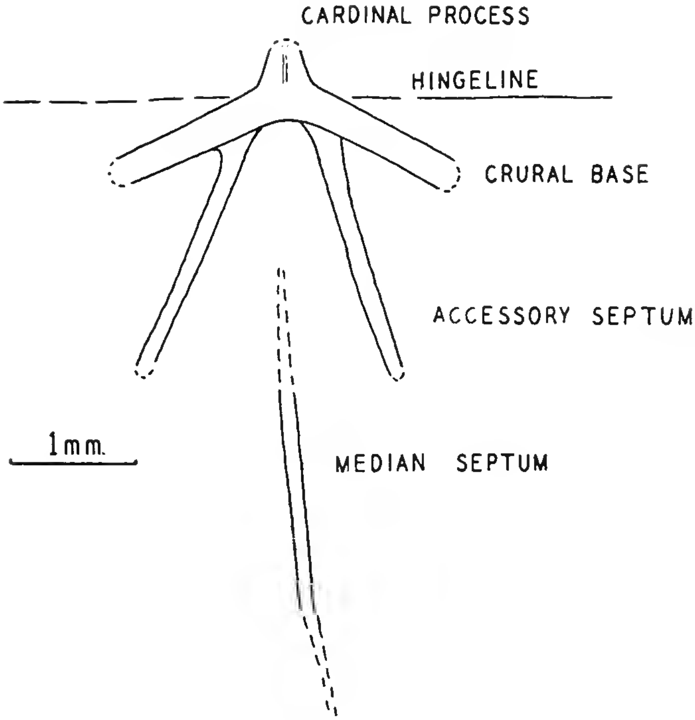

Fig. 2.—Camera lucida drawing of cardinalia of *Chonetes cresswelli.*

Chonetes is generally described as having a quadrilobate cardinal process 'divided by a narrow median and two broader lateral grooves' (Schuchert 1913, p. 389). One groove, which is probably the median one, shows plainly as a narrow ridge in the skeinkern, and there is but indecisive evidence of further subdivision.

A dorsal valve of *C. cresswelli* has also been found in the reddish siltstone from Hull Road, Lilydale (loc. 1). It shows the arrangement of septa described above, but the cardinal process is poorly preserved (N.M.V. 14714, 14715 counterparts).

Chonetes cresswelli *with annular spine*

In 1945 the writer described *C. gaskini* as having an annular spine. A specimen of *C. cresswelli* (N.M.V. 15133) has now been discovered with a similar structure. It was collected from 'Lilydale' (no doubt loc. 2) by Rev. A. W. Cresswell. More than a dozen rings can be seen on the mould of the spine.

Chonetes bowieae Gill

(Pl. III, fig. 16)

Chonetes bowieae Gill, 1945, p. 136, Pl. VIII, figs. 1-2.

Generally the palintrope in *Chonetes* approximates the thickness of the valve wall so that it extends very little into the valve cavity. In *C. bowieae,* however, the palintrope is comparatively high and thick, extending into the body cavity of the ventral valve, as is shown by the plate-like recesses in steinkerns (Pl. III, fig. 16). The median septum continues right to the posterior margin of the valve, and has a slightly widened and flattened area between the teeth. The teeth have a triangular

outline in cross-section, and are directed apart slightly. Each tooth is continuous with a plate that extends about 1·5 mm. into the valve cavity. The plate-like structures were originally referred to as 'dental lamellae almost parallel with the hingeline,' but this is misleading. The better preserved structures now figured reveal their true character.

The impressions of the outer ends of three of the spines of the external mould of the holotype provide evidence that the spines were hollow. The material which infilled the hollows of the spines remains as fine shafts set in the centres of the cavities left by the dissolving away of the calcium carbonate of the spines.

Chonetes micrus sp. nov.

(Pl. III, figs. 6-11; Text fig. 4)

Type material. 1. Holotype consisting of the steinkern (N.M.V. 14698) and external mould (N.M.V. 14699) of a ventral valve in a brown and grey fine-grained siltstone from Hull Road, Mooroolbark (for map see Gill 1940). The matrix was originally grey, and it turns brown on weathering, apparently through the oxidation of the iron present.

2. Paratype consisting of the steinkern (N.M.V. 14700) and external mould (N.M.V. 14701) of a dorsal valve in the same matrix and from the same locality.

The trivial name is from the Greek word 'micros' meaning 'small', a reference to the diminutive size of the species compared with those already described from the Lilydale fauna.

Occurrence. The species occurs at Hull Road, Mooroolbark (types), and at Lilydale (e.g. N.M.V. 14702, collected by Rev. A. W. Cresswell from the 'Lilydale mudstone,' which is very probably loc. 2).

Description of Holotype. Ventral valve convex, sub-semicircular in outline, 5 mm. wide and 3·5 mm. long when measured in plan, and 4·5 mm. long when measured along the midline profile. Valve tumid, the midline profile rising about 1·5 mm. above the line joining the umbo and the midpoint of the anterior margin. The highest point of the profile is about a third of the way from the umbo to the anterior margin. There is a tendency for the valve to flatten on the cardinal extremities. Hingeline straight and less than that of the greatest width of the valve, the cardinal angles being obtuse.

Median septum 1·25 mm. long, thin. The steinkern is broken away a little at the umbo, revealing that the septum is high at the umbonal end, but half way along its length is reduced to a linear ridge. The umbo is insignificant and does not extend beyond the hingeline; palintrope linear. In the interior of the valve, on the cardinal extremities and on the lateral borders, are comparatively large papillae set in the intercostellar spaces of the steinkern. There are about twenty on each side of the valve along with some smaller ones.

The external mould shows that there is a slight depression down the midline of the valve, i.e. an incipient sinus. Prosopon costellate, but the cardinal extremities are almost smooth. Costellae number about 34 on the margin, and 22 half way down the valve: the primary costellae gradually widen from the umbo and then bifurcate when about half the length of the valve, but those nearest the cardinal extremities are not bifurcated. The costellae are rounded in cross-section although their crests are somewhat flattened by the time they attain their full width. The furrow occupying the midline of the valve between the two central costellae is a little more pronounced in the posterior half of the valve than are the others.

Description of Paratype. Greatest width 6·5 mm. and length 4·5 mm. (or 5 mm. following the profile). The valve is concave, its midline rising about 1 mm. above the line joining the umbo and the midpoint of the anterior margin. Thus the body cavity between the two valves must have been small. Palintrope linear, and approximately at right angles to the posterior border of the valve. Cardinal process quadrilobate as shown in Fig. 3, and set in the plane of the palintrope; the lobes jut posteriorly at right angles to the palintrope. Crural bases fine, and splayed apart at an angle of the order of 130°; distally they tend to turn parallel to the hingeline. Merged into the cardinal process is a low flat-topped median platform or septum about 1 mm. long and 0·25 mm. wide; it terminates abruptly anteriorly. The whole interior of the valve is papillose, elongate papillae of the ramp type (Gill 1950c) being aligned to the costellae of the external surface.

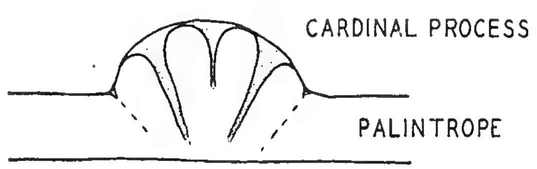

Fig. 3.—Diagram of the cardinal process of *Chonetes micrus* sp. nov.

Prosopon similar to that of the ventral valve, the cardinal extremities being relatively smooth and the rest of the surface costellate, 36 costellae being counted. Increase by bifurcation, but one intercalation noted. As in the ventral valve the midline furrow is a little more pronounced than the others.

Comment. Special midline structures are not unusual in chonetids (e.g. *Chonetes melbournensis* has a more prominent central stria in the ventral valve, while *C. cresswelli* and related forms have a median ventral sinus) and to this class belongs the slightly accentuated median intercostellar furrow of this species.

Spines do not appear on the type specimens but are to be seen on specimens 14705-14706, which show two long thin spines on one side of the umbo so placed as to suggest that this was the full number for each side, i.e. a total of four. The spines are thus of similar number and type to those found on *Chonetes ruddockensis* and *C. teicherti*. From both these species, however, *C. micrus* is readily distinguished by its strongly papillose interior and the nature of the prosopon as well as other details.

Genus **Notanoplia** Gill 1950

Notanoplia loyolensis sp. nov.

(Pl. III, figs. 1-4)

Leptaena rhomboidalis Chapman, 1913, pp. 103-104, Pl. 10, figs. 6-7.

Type material. Holotype consisting of the steinkern of a ventral valve in fawn siltstone from 'Loyola, near Mansfield,' Victoria (N.M.V. 12403).

Description. Ventral valve mildly convex, subquadrate in outline, 6·5 mm. wide and 6 mm. long. Beak prominent for genus. Strong teeth situated at inner ends of teeth bases. There are seven septa on the interior of the valve, as follows:

1. Median septum, which begins on the umbo and extends for a little more than two-thirds of the length of the valve, ending abruptly. There is a row of pits along the top of the septum, which appear as a row of papillae in the steinkern.

2. Two main accessory septa, which are roughly half way between the median septum and the hingeline, but actually nearer the latter. They begin anteriorly to the umbo, not connecting with the median septum, and end a short distance from the margin of the valve; both terminations are abrupt. These septa also have a row of pits along the top.

3. Two short septa, of similar character, between the last-described septa and the hingeline.

4. Two septa, or rather callus mounds (because of their indefinite shape), without pits, between the median septum and the main accessory septa.

Comment. The holotype was described and figured by Chapman (as shown in the synonymy) as a brachial valve of *Leptaena rhomboidalis*, the various septa being interpreted as 'brachial impressions.' Species of *Notanoplia* with three septa (*N. australis* and *N. pherista*), and with five septa (*N. withersi*) have been described, and the new species is readily recognized by its possession of seven septa. The presence of pits along the ridge edges of the septa is also a feature not described before. Specimens of *Notanoplia* with seven septa and associated pits have been noted in a piece of sandstone or grit from '12 chains S.W. of low saddle at head of right branch of Cable's Creek,' which is a tributary on the west side of the Big River in the Enoch's Point District. This bed is near the base of the Yeringian strata of that area (Harris and Thomas 1942, map and section).

Notanoplia australis (Gill)

Anoplia australis Gill, 1942, pp. 38-39, Pl. IV, fig. 8.
A. australis Gill, 1945, p. 144.

A new record of occurrence is reported through the help of Messrs. J. Talent and J. Neal, who presented to the National Museum a specimen showing both valves opened out flat but still joined together (N.M.V. 15135 and 15136 counterparts) from 'Flowerfield Quarry, near Coldstream.'

It has been noted that there is a smaller variety of this species present at Ruddock's Quarry and many other Lower Yeringian localities, while in the Upper Yeringian the species is represented by a larger variety. There are also other small differences in structure. The new record is of the larger type, being 8 mm. wide and 7 mm. long. The holotype is of the larger kind, measuring 6 mm. wide, while the smaller kind is typically 3·5 mm. to 4 mm. wide.

B. Middle Devonian Species.

Genus **Chonetes** Fischer de Waldheim 1837

Chonetes australis McCoy

(Pl. III, figs. 18, 19, 21; Text figs. 4-7)

Chonetes australis McCoy, 1876, pp. 17-18, Pl. XXV, figs. 3-5.

In 1876 McCoy described *Chonetes australis* and figured two specimens occurring on one piece of rock. He did not indicate where these type specimens came from, merely stating that the species is 'Very abundant in the Middle Devonian limestone of Lucknow, E. of Mitchell River: also of Buchan.' McCoy's figured specimens consist of a large and a small ventral valve. The interior of the ventral valve has not been previously described, nor the nature of the dorsal valve. With the help of material from the Mines Department of Victoria, the University of Melbourne Department of Geology, and the National Museum, this species has now been studied. As the types have not yet been located, the species is illustrated by various hypotypes.

Description of Ventral Valve. The specimen chosen for figuring (Pl. III, fig. 19) and description is a ventral valve (M.D.V. 47639), collected by Dr. C. Teichert from a little below the top of the Cave Limestone, Slocombe's Creek, half a mile north of East Buchan Road. The matrix is a bluish-grey dense crystalline limestone. The measurements of the valve are:

Greatest width	15 mm.
Width along hingeline	13 mm.
Greatest length	10 mm.

These measurements are in one plane and not following the profile of the shell. The midline profile rises about 2·5 mm. above a line joining the centres of the anterior and posterior margins; the highest part of the profile is in the middle of the valve. Outline semi-circular, the cardinal angles being slightly obtuse, and the greatest width of the valve about one third of the way along its length. The hingeline is straight, and the umbo inconspicuous. The valve is evenly tumid except for a flattening on the cardinal extremities and a tendency to develop a median longitudinal sinus. Bases of spines along the ventral margin, and a part of one, show that these were set at a slightly oblique angle to the hingeline, as figured by McCoy. Surface of valve multicostellate. The costellae are rounded in cross-section, and are about the same width as the interspaces. Increase is both by bifurcation and intercalation. There are about 45 costellae when numbered half way down the length of the valve and about 60 when counted along the anterior margin. The costellae radiate from the umbo where they are very fine; a young shell thus appears to have a finer costellation. Under the microscope exceedingly fine concentric growth lines can be seen. The three costellae occupying the incipient sinus down the middle of the valve are slightly finer than those on each side of them.

Description of Dorsal Valve. (Plate III, figs. 18, 21). The specimen is in greyish limestone from just above the *Spirifer Limestone*, immediately north of the north end of Moon Road, Buchan; collected by Dr. C. Teichert (M.U.G.D. 1984). Valve concave; the outline and costellation are comparable with those of the ventral valve. Measurements:

Greatest width	11 mm.
Length (incomplete)	5·5 mm.

There is a short median septum, about one millimetre long. Traces of accessory septa are present (Pl. III, fig. 21). On each side of the median septum at the posterior end, and almost in continuity with it, there is a short ridge about half the length of the septum, and forming an angle of about 45° with it. The septum and ridges constitute in form a minute arrowhead. The ridges may be interpreted as crural bases.

The arrangement of the cardinalia is very similar to that occurring in *C. teicherti*.

Special Preparations

In order to elucidate structures in *C. australis* not appearing in field specimens, special preparations were made by grinding, etching, and calcining. These are now described with a few notes on technique. Line drawings were made with the help of a camera lucida. It was found that if a flat view of the specimen being drawn were required, then the use of paper of the same colour as the fossil was helpful. More often, however, a view of the specimen providing contrast was required, and in this case it was found that a contrasting shade of paper was helpful. Red brought out the relief in fawn-coloured fossils like the specimen of *C. cresswelli,* and yellow did the same for the bluish limestone containing *C. australis.*

1. *Specimen M.D.V. 47556.* The Geology Department of the University of Melbourne has designed a much improved type of fossil serial section grinder, a description of which is to appear elsewhere. It provides a thorough control of the direction of section, and a precision device lowers the fossil on to the grinding plate by movements measurable to 0·01 mm. There is thus no difficulty in cutting series of sections 0·1 mm. apart. This machine was employed for the ground sections made during the present investigation. The fossil selected was a ventral valve of *C. australis* with spines from 35 feet below the top of the Cave Limestone, south of Fairy Cave. The specimen was ground until one of the spines was clearly sectioned transversely. All except the ground surface was covered with collodion, and then the specimen was etched with concentrated hydrochloric acid, the collodion protecting the shell from attack by the acid. The result is given in Fig. 4, which shows clearly that the spines in *C. australis* were hollow.

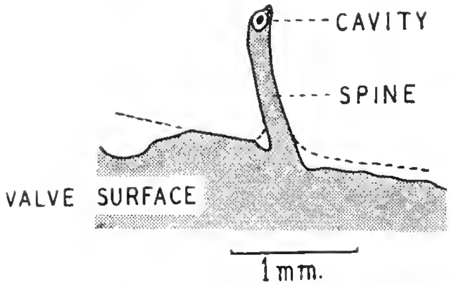

Fig. 4.—Camera lucida drawing of a specimen of *Chonetes australis* showing a spine sectioned by grinding and then etched with acid to demonstrate the cavity or lumen. The stippled area is that part of the fossil not obscured by matrix.

2. *Specimen M.D.V. 47557.* Another specimen of *C. australis* from the same locality as M.D.V. 47556 was then ground at right angles to the direction of the previous section in such a way as to provide a longitudinal section of a spine. Owing to the curve of the spine, the section is slightly oblique. The ground surface was then etched, and Fig. 5 is a camera lucida drawing of the result. When examined

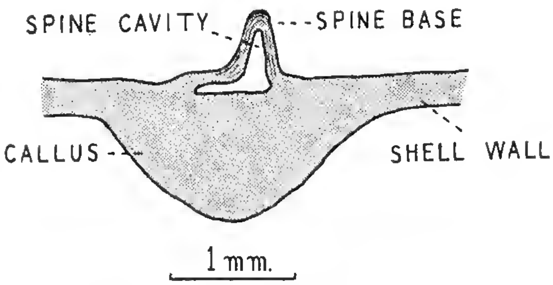

Fig. 5.—Camera lucida drawing of a section cut obliquely through a spine of *C. australis.* The section was ground and then etched with acid.

under a stereoscopic microscope, the growth lines of the spine as brought out by etching can be distinctly seen, indicating a lamellar structure. The cavity or lumen of the spine extends laterally towards the cardinal angle, and is reminiscent of subsurface extensions of spine cavities in productids figured by Dunbar and Condra

(1932, fig. 11). The spine cavity in the specimen studied does not connect with the body cavity, although it must have done so originally for the spine to be grown. Once the spine is grown, the orifice leading to the spine cavity apparently tends to become blocked by secondary calcareous deposition. This is not just the overall thickening of the valve by the addition of new lamellae on the interior, because it is so thick and localized. It rather falls within the category of a callus. No growth lines indicating lamellar structure could be made out in this part of the section in spite of acid etching.

3. *Specimen N.M.V. 15134.* This was collected by Mr. F. S. Colliver from Buchan, Victoria, and kindly presented to the National Museum. It is a mature ventral valve of *C. australis,* being a little larger than most. The whole specimen was immersed in dilute hydrochloric acid and left until a general reduction of the valve had taken place, then stood with the beak in the acid so as to bring out the interior umbonal structures. Some difficulty is usually experienced in controlling this part of the process, as it is all too easy to lose desired parts of the specimen. This has been overcome by a technique of differential etching. It was found that a tube of 1·5 mm. diameter (inside measurement) tapered at one end in the shape of an eye-dropper to 0·75 mm. diameter works well. This was dipped in a watch-glass of 12N HCl, which was drawn into the tube by capillary attraction, but on touching the fossil the acid ran out again due to surface tension effects. The tube (3 inches is a convenient length—7.5 cm.) was kept touching the fossil until the required amount of acid had run out, and by lifting it the acid ceased running from the tube. This differential etching was carried out under a low-power set-up of a wide-field binocular microscope. The method described gives safe and easy control of a dangerous reagent, and permits a controlled etching of the finest structures.

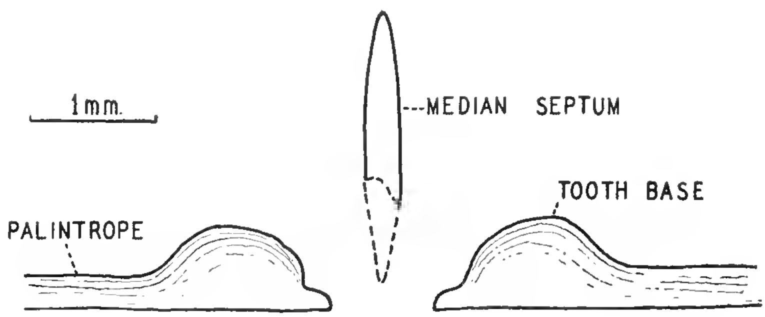

FIG. 6.—Structures on the interior of the ventral valve of *C. australis* as obtained by acid etching. Camera lucida drawing.

Figure 6 shows the interior umbonal structures of *C. australis* as obtained by etching only. The palintrope is shown to be continuous with the teeth bases (cf. Fig. 8), and the lines brought out by etching indicate the manner of growth of these structures. Between the teeth is the delthyrium. The median septum is seen to be broadest in the middle at this line of section. The muscle areas in *C. australis* are not usually defined, but in this old valve the area can be made out as a slightly excavated zone of sub-circular outline. The greatest length is approximately 7 mm. and the width 8 mm.

4. *Specimen N.M.V. 1222.* The method of calcining was employed on another specimen of *C. australis* from Buchan in order to elucidate the relationship of the

median septum to the other umbonal interior structures. After the valve had been calcined in the oxidizing flame of a Bunsen burner, the shell material was chipped and scraped away, leaving structures as shown in Fig. 7. This preparation shows that the septum, teeth and palintrope meet and fuse in the middle of the posterior margin. The T-shape of palintrope and septum, strutted together by the over-spanning shell-wall, constitutes a mechanically sound structure in which to set the articulating teeth. The teeth are placed in the strongest place, viz. the junction of the septum, palintrope, and shell wall (*vide* Gill 1950c).

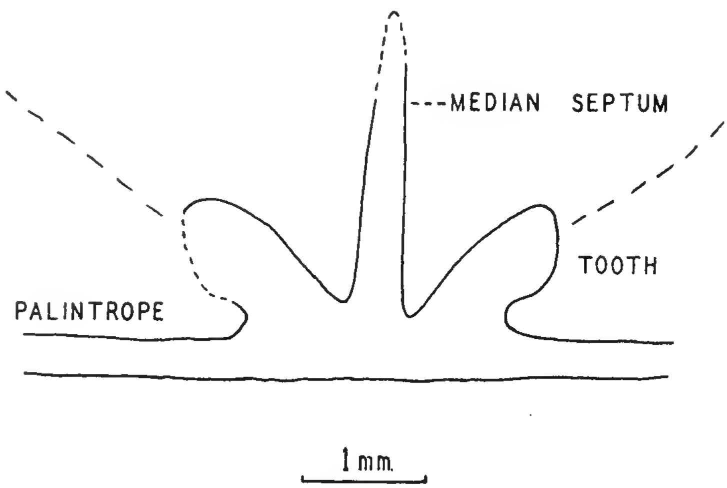

FIG. 7.—Camera lucida drawing of preparation from calcined ventral valve of *C. australis*. The broken lines from the teeth indicate the boundaries of the muscle field as suggested by a slight excavation of the valve.

Comment. Chapman (1903, p. 77) compared and contrasted *C. cresswelli* and *C. australis*, Gaskin (1943, p. 91) recorded *C. australis* from the Bindi area, and Teichert (1948, pp. 61-62) recorded it from localities in the Buchan area.

No dorsal valve satisfactory for reproduction has been found yet, but it is apparently concave, and the cardinalia are in the form of an arrowhead like those of *C. teicherti,* but proportionately larger. *C. australis* is like most of the Victorian Devonian *Chonetes* in its general outlines and in having a short ventral median septum. It differs by its possession of spines set obliquely to the hingeline, and in the character of its cardinalia. McCoy compared *C. australis* with *C. sarcinulatus,* but now that the interior structures are known, it is clear that there is really very little comparison.

Chonetes buchanensis sp. nov.

(Pl. III, figs. 17, 20; Text fig. 8)

Type material. 1. Holotype consisting of a ventral valve preserved in bluish-grey crystalline limestone (M.D.V. 48690) from big eastward bend in the Gelantipy Road, half a mile south of Murrindal State School. Collected by Dr. C. Teichert.

2. Paratype consisting of a calcined ventral valve (M.D.V. 48824). Same locality.

3. Hypotype consisting of a ventral valve broken in such a way as to reveal the umbonal structures. The specimen is M.D.V. 48825B, occurs in a bluish-grey

crystalline limestone, and comes from the ridge east of Rocky Camp, 215 feet above the top of the Cave Limestone.

Description of Holotype. Ventral valve sub-semicircular, with straight hinge-line and well rounded anterior margin. Measured in one plane, the width is approximately 22 mm. (the cardinal angles are incomplete), and the length 18 mm. Following the midline profile, the length is 28 mm. The valve is obese, the midline profile rising about 9 mm. above the plane uniting the anterior and posterior borders. The profile is steeper at the posterior end than at the anterior end, the highest point being about one third of the length of the valve from the umbo. The tumidity is much reduced about the cardinal angles. There is no longitudinal median sinus as in *Chonetes robustus.* Prosopon (for term see Gill 1950d) consists of low rounded costellae, which increase by bifurcation and intercalation. Costellae and interspaces of about equal width. Costellae number about 34 in the middle of the valve, and about 40 on the anterior margin. These numbers are minima as the cardinal angles are incomplete. The costellae tend to be irregular or sinuous, especially towards the anterior margin. Growth lines are present and these become more pronounced and wavy towards the anterior margin. The stumps of two or three spines can be recognized. In a couple of places on the valve, decortication has revealed the pseudo-punctate character of the subsurface layer of the shell wall.

Description of Paratype. Ventral valve 25 mm. wide and 20 mm. long measured in one plane. Length following profile 30 mm. Profile as holotype and rising about 9 mm. above the plane uniting the posterior and anterior margins. Costellae number about 36 in the middle of the valve, and about 42 on the anterior margin. The uneven nature of the costellae, the wavy growth lines, and the pseudo-punctation show well on the calcined specimen. Palintrope about 0·75 mm. wide. Teeth small. Fine median septum which appears to reach 6 mm. from the umbo.

Description of Hypotype. The umbonal structures are illustrated by a camera lucida drawing in Fig. 8. The structures are comparatively large. The teeth are

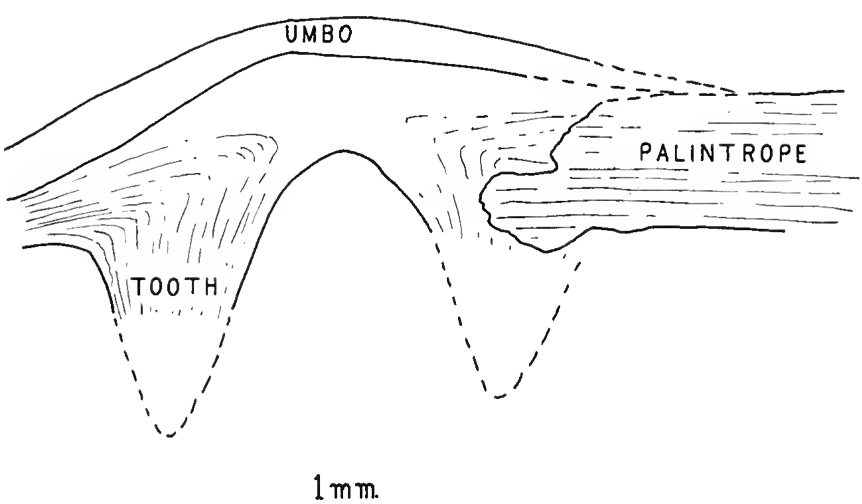

FIG. 8.—Camera lucida drawing of umbonal structures of the ventral valve of *Chonetes buchanensis* sp. nov. Broken lines indicate areas covered with matrix.

shown by the growth lines to grow outwards and downwards. The palintrope shows as a separate plate with a different direction of growth; it is of a slightly different colour in this specimen from the rest of the shell. Some of the etched specimens of *Chonetes australis* also show that the palintrope is probably a separate plate.

Comment. *Chonetes buchanensis,* which derives its name from the district of its origin, is clearly a member of the *Chonetes robustus* gens. From this species it differs in size, and in the absence of the median sinus. The irregular costellae and wavy growth lines are also a difference, and these features suggest group gerontism. *C. buchanensis* is probably nearest *C. baragwanathi* (Gill 1949), which is likewise of large size and possesses growth lines, but has a median sinus and is of different proportions. The costellae are sharp in *Chonetes baragwanathi* but rounded in *C. buchanensis.* Although these two species are fairly closely related, the latter possesses more marked gerontic features than the former, and this suggests that it is younger stratigraphically.

Chonetes teicherti sp. nov.

(Pl. III, figs. 12-15)

Type material. 1. Holotype consisting of a ventral valve preserved as counterparts of a ventral valve (M.U.G.D. 1979-1980) preserved in dark bluish-grey crystalline limestone from just above the Cave Limestone north of the north end of Moon Road, Buchan. Collected by Dr. C. Teichert, after whom I have the pleasure of naming the species.

2. Paratype consisting of the interior of a dorsal valve preserved in dark bluish-grey silty limestone from McLarty's Gully, Buchan District (M.U.G.D. 1982-1983 counterparts).

Description of Holotype. Valve small, sub-quadrate in outline and mildly convex. Width 5·5 mm. and length 3·75 mm., but the actual anterior margin is missing; full length probably 4·25 mm. Median longitudinal profile has its highest point about one third of its length from the midpoint of the posterior margin; the profile rises about 0·75 mm. above the plane joining the anterior and posterior margins. Valve costellate, there being about 45 somewhat flatly rounded costellae, each interspace approximating in width that of the contiguous costella. As is commonly the case in this genus, the costellae tend to be finer on the cardinal extremities. Increases appear to be by both intercalation and bifurcation. There is preserved a long fine spine, 1·75 mm. long, and situated the same distance from the umbo. It is set at right angles to the hingeline, and where it enters the valve, it possesses a thickened base. Growth lines cover the valve, being particularly prominent in the umbonal area, where their occurrence is of the order of 12 per mm. The umbo is inconspicuous.

Description of Paratype. Valve 4·5 mm. wide and 3 mm. long approximately, the margin not being complete; slightly concave. Costellae about 40 in number; low and rounded in cross-section. Growth lines prominent. Short, stumpy median septum about 1 mm. long. On each side of this septum, making an angle of about 45° with it, is a short ridge thinner than the septum and about 0·5 mm. long. They almost connect with the septum, but not quite.

Comment. On many specimens of rock, *Chonetes teicherti* occurs in great numbers, literally covering the surface of the layer; this can be seen for instance on the piece of limestone carrying the paratype. On scanning a large number of specimens, it is seen that the ventral valve commonly has a stronger central costella and the dorsal valve sometimes has a corresponding linear depression down the

midline. The ventral valve may also have the posterior part of its muscle field excavated, showing as two nodes in the steinkern. It is also clear that the species possesses two spines on each side of the umbo; a number can be seen on the specimens referred to, and they are always of the long, fine type. The commonest width for the species is 4 mm. to 4·5 mm., and the largest specimen observed was 6 mm. wide.

The new species is readily recognized by its small size, the prominent and regular growth lines (they are not wavy and aberrant as in gerontic forms), the nature of the spines, and the structures of the dorsal valve. With most species of *Chonetes* there is difficulty in obtaining dorsal valves as they are apparently weaker in construction than the ventral valves and break up more readily. When concave the dorsal valve is held within the shielding ventral valve, and when planate is like a lid to the ventral valve, in both cases being considerably protected by the other valve; it therefore did not need to be as strong as the ventral valve. However, in *C. teicherti* dorsal valves occur more frequently than is the general rule, and from this it is inferred that the dorsal valve was nearer the ventral one in strength.

Chonetes teicherti and *C. australis* occur together on the same slabs, and the difference in size is the first thing that claims attention. The new species has also been found at Slocombe's Creek, half a mile north of the East Buchan Road, near the top of the Cave Limestone (M.D.V. 47606). The species is thus characteristic of both the top of the Cave Limestone and of the overlying formation.

Acknowledgments

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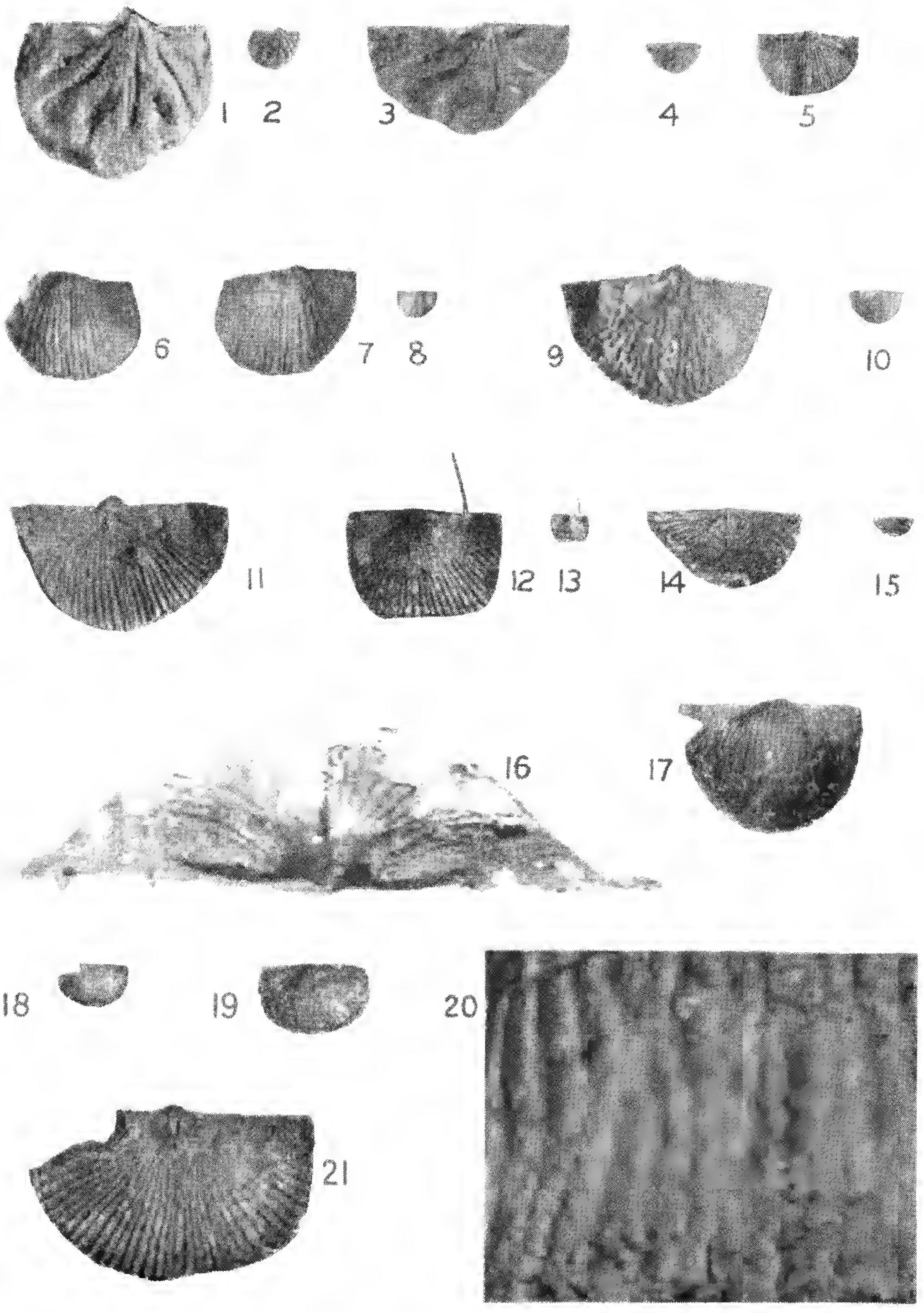
Description of Plate III

Fig. 1.—*Notanoplia loyolensis* sp. nov. HOLOTYPE. N.M.V. 12403 X4.
Fig. 2.—*N. loyolensis* sp. nov. HOLOTYPE, natural size.
Fig. 3.—*N. loyolensis* sp. nov. HOLOTYPE. Umbonal view to show teeth (represented by holes in steinkern). X4.
Fig. 4.—*N. loyolensis* sp. nov. HOLOTYPE. Umbonal view, natural size.
Fig. 5.—*Chonetes cresswelli* Chapman. HOLOTYPE. N.M.V. 652, natural size.
Fig. 6.—*Chonetes micrus* sp. nov. HOLOTYPE external mould of ventral valve. N.M.V. 14699 X4.
Fig. 7.—*C. micrus* sp. nov. HOLOTYPE steinkern of ventral valve. N.M.V. 14698 X4.
Fig. 8.—*C. micrus* sp. nov. HOLOTYPE steinkern, natural size.
Fig. 9.—*C. micrus* sp. nov. PARATYPE steinkern of dorsal valve. N.M.V. 14700 X4.
Fig. 10.—*C. micrus* sp. nov. PARATYPE steinkern, natural size.
Fig. 11.—*C. micrus* sp. nov. PARATYPE external mould of dorsal valve. N.M.V. 14701 X4.
Fig. 12.—*Chonetes teicherti* sp. nov. HOLOTYPE ventral valve. M.U.G.D. 1979 X4.
Fig. 13.—*C. teicherti* sp. nov. HOLOTYPE ventral valve, natural size.
Fig. 14.—*C. teicherti* sp. nov. PARATYPE dorsal valve (incomplete). M.U.G.D. X4.
Fig. 15.—*C. teicherti* sp. nov. PARATYPE dorsal valve, natural size.
Fig. 16.—*C. bowieae* Gill. Umbonal view of a steinkern. X4.
Fig. 17.—*Chonetes buchanensis* sp. nov. HOLOTYPE ventral valve. M.D.V. 48690, natural size.
Fig. 18.—*Chonetes australis* McCoy. HYPOTYPE dorsal valve. M.U.G.D., natural size.
Fig. 19.—*C. australis* McCoy. HYPOTYPE ventral valve. M.D.V. 47639, natural size.
Fig. 20.—*C. buchanensis* sp. nov. PARATYPE ventral valve. M.D.V. 48824. Part of middle anterior of valve to show irregular costellae and growth lines. X6.
Fig. 21.—*C. australis* McCoy. HYPOTYPE dorsal valve. X4.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Drummond, F. H., Ph.D., B.Sc., Zoology Department, The University, Carlton, N.3 .. 1933
Edwards, A. B., D.Sc., Ph.D., D.I.C., Geology Department, The University, Carlton, N.3 1930
Esserman, N. A., B.Sc., A.Inst.P., National Standards Laboratory, University Grounds, Sydney, N.S.W. 1923
Fitts, Clive H., M.D., 14 Parliament Place, Melbourne, C.2 1945
Gill, Edmund, D., B.A., B.D., 26 Winifred Street, Essendon, W.5 1938
Gray, K. Washington, M.A., Ph.D., 90 William Street, Melbourne, C.1 1946
Grice, J. Hugh, "Highfield," Lilydale 1938
Grimwade, Sir Russell, Kt.B., C.B.E., B.Sc., 342 Flinders Lane, Melbourne, C.1 .. 1912
Harding, N. T., B.M.E., 34 Wakefield Street, Hawthorn, E.2 1951
Hartman, S., c/o The James Bell Machinery Co. Pty. Ltd., 200 King Street, Melbourne, C.1 1946
Hartung, Prof. E. J., D.Sc., Ph.D., The University, Carlton, N.3 1923
Hills, Prof. E. S., D.Sc., Ph.D., The University, Carlton, N.3 1928

Hordern, A., 242 Walsh Street, South Yarra, S.E.1. 1940
Jack, R. Lockhart, B.E., D.Sc., F.G.S., 54 Clowes Street, South Yarra, S.E.1 1931
James, A. V. G., B.A., D.Sc., 23 Bayview Crescent, Black Rock, S.9 1917
Jutson, J. T., D.Sc., LL.B., 9 Ivanhoe Parade, Ivanhoe, N.21 1902
Kannaluik, W. G., D.Sc., Physics Department, The University, Carlton, N.3 1946
Kesteven, H. Leighton, D.Sc., M.D., Palmwoods, Queensland 1945
Kimpton, V. Y., 16 Lansell Road, Toorak. S.E.2 1946
Lang, P. S., B.Agr.Sc., Titanga, Lismore 1938
Leeper, Assoc. Prof. G. W., M. Sc., Chemistry Department, The University, Carlton, N.3 1931
Lewis, Essington C. H., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1945
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary Road, Burwood, E.13 1921
Lord, E. E., 77a Durham Road, Surrey Hills, E.10 1950
MacCallum, Prof. P., M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., The University, Carlton, N.3 1925
McPherson, Sir Clive, C.B.E., 216 Domain Road, South Yarra, S.E.1 1946
Manning, C. T., "Illoura," 424 St. Kilda Road, Melbourne, S.C.2 1950
Martin, Prof. L. H., Ph.D., F.Inst.P., The University, Carlton, N.3 1945
Medley, Sir John, Kt.B., M.A., "Wickham," Harkaway, via Berwick 1945
Miller, E. Studley, 396 Flinders Lane, Melbourne, C.1 1921
Miller, Leo F., "Moonga," Power Avenue, Malvern, S.E.4 1920
Millikan, C. R., M.Agr.Sc., Plant Research Laboratory, Swan Street, Burnley, E.1 .. 1941
Montgomery, J. N., c/o Australasian Petroleum Company, 37 Queen Street, Melbourne, C.1 1945
Moore, K. Byron, 11 Mona Place, South Yarra, S.E.1 1945
Morrison, P. Crosbie, M.Sc., Herald Office, 44-74 Flinders Street, Melbourne, C.1 .. 1938
Murdoch, Sir Keith, Albany Road, Toorak, S.E.2 1945
Murphy, H. D., Mornington 1950
Nicholas, George R., 48 Lansell Road, Toorak, S.E.2 1934
Olsen, C. O., B.A., Dip.Ed., 46 Clendon Road, Toorak, S.E.2 1945
Orr, R. Graeme, M.A., B.Ch., 9 Heyington Place, Toorak, S.E.2 1935
Patton, R. T., D.Sc., M.F. (Harv.), D.I.C., 13 Hartley Avenue, Caulfield, S.E.8 .. 1922
Pescott, R. T. M., M.Agr.Sc., F.R.E.S., National Museum, Russell Street, Melbourne, C.1 1944
Pitt, E. R., B.A., F.L.A., "Corrabert," 210 Orrong Road, Toorak, S.E.2 1946
Preston, H. E., 34 Coppin Grove, Hawthorn, E.2 1949
Quayle, E. T., B.A., 27 Collins Street, Essendon, W.5 1920
Reid, J. S., 498 Punt Road, South Yarra, S.E.1 1920
Rivett, Sir David, K.C.M.G., M.A., D.Sc., 474 St. Kilda Road, Melbourne, S.C.2 .. 1911
Rogers, J. S., M.C., B.A., D.Sc., F.Inst.P., The University, Carlton, N.3 1924
Sayce, E. L., B.Sc., F.Inst.P., Defence Research Laboratories, Maribyrnong, W.3 .. 1924
Simpson, H. P., 8 Knutsford Street, Balwyn, E.8 1948
Spicer, P. O., 6 Inverness Way, Balwyn, E.9 1946
Stokes, Dr. H. Lawrence, 417 St. Kilda Road, Melbourne, S.C.2 1945
Sullivan, W., 326 Exhibition Street, Melbourne, C.1 1943
Sunderland, Prof. S., D.Sc., M.B., B.S., The University, Carlton, N.3 1945
Tattam, C. M., Ph.D., D.Sc., Geology Department, The University, Carlton, N.3 .. 1945
Teichert, C., D.Sc., Geology Department, The University, Carlton, N.3 1945
Thomas, D. E., D.Sc., Mines Department, Melbourne, C.2 1929
Thomas, D. J., M.D., 81 Collins Street, Melbourne, C.1 1924
Tiegs, Prof. O. W., D.Sc., F.R.S., The University, Carlton, N.3 1925
Timcke, E. W., 15 Faircroft Avenue, Glen Iris, S.E.6 1950
Tulloh, N. M., B.Agr.Sc., Animal Health Laboratory, C.S.I.R.O., Flemington Road, Parkville, N.2 1950
Turner, Prof. J. S., M.A., Ph.D., M.Sc., The University, Carlton, N.3 1938
Vail, Col. L. E., E.D., 26 Chaucer Street, Canterbury, E.7 1939
Wadham, Prof. S. M., M.A., Agr.Dip., The University, Carlton, N.3 1932
Wettenhall, Dr. Roland R., "Aberfeldie," 357 Toorak Road, Toorak, S.E.2 1938
White, Dr. A. E. Rowden, 14 Parliament Place, Melbourne, C.2 1938
Wilcock, A. A., B.Sc., B.Ed., Geology Department, The University, Carlton, N.3 .. 1934
Willis, A. G., M.Sc., Zoology Department, The University, Carlton, N.3 1949
Wood, Prof. G. L., M.A., Litt.D., The University, Carlton, N.3 1933
Wright, Prof. R. D., D.Sc., M.B., M.S., F.R.A.C.S., F.R.A.C.P., The University, Carlton, N.3 1941

Country Members

Adams, H. E., "Danedite," Weerite 1945
Baldwin, J. G., B.Sc., B.Agr.Sc., Commonwealth Research Station, Merbein 1949
Buley, J. V., B.Sc., Engineering School, The University, Carlton, N.3 1946
Corney, Mrs. A. D., B.Sc., 17 Ratho Street, New Town, Tasmania 1945
Currie, Mrs. Ian, "Seven Oaks," Euroa 1941
Felstead, Dr. J. G. R., P.O. Box 30, Horsham 1945
Glaessner, M. F., Ph.D., D.Sc., Geology Department, The University of Adelaide, Adelaide, South Australia 1939
Gloe, C. S., M.Sc., Irrigation and Water Supply Commission, Box 553H, G.P.O., Brisbane, Queensland 1944
Harris, W. J., B.A., D.Sc., P.O. Box 34, Warragul 1914
Hill, Dorothy, D.Sc., Geology Department, The University of Queensland, Brisbane, Queensland 1939
Hope, G. B., B.M.E., "Carrical," Hermitage Road, Newtown, Geelong 1918
Jenkin, J. J., National Museum, Russell Street, Melbourne, C.1 1945
Knight, J. L., B.Sc., Mines Department, Melbourne, C.2 1944
Mack, G., B.Sc., Queensland Museum, Brisbane, Queensland 1943
Mann, S. F., Melbourne Club, 36 Collins Street, Melbourne, C.1 1922
Martin, Miss Gwen J., B.Sc., 101 Waterdale Road, Ivanhoe, N.21 1946
Middleton, Dr. F. G., 79 The Esplanade, Geelong 1946
Payne, T. E. Neville, "Woodburn," Kilmore 1945
Prentice, H. J., B.Sc., Strangways 1936
Rose, F. G. G., Division of Regional Planning, Post-war Reconstruction, Canberra, A.C.T. 1944
Tindale, B., Yarra Junction 1951
Trebilcock, Lieut. Col. R. E., M.C., Wellington Street, Kerang 1921
White, R. A., B.Sc., School of Mines, Bendigo 1918
Yates, H., M.Sc., School of Mines, Ballarat 1943

Associate Members

Aitken, Miss Y., M.Agr.Sc., School of Agriculture, The University, Carlton, N.3 .. 1936
Alderman, A. R., M.Sc., Ph.D., F.G.S., Box 4331, Melbourne, C.1 1942
Ashton, D. H., B.Sc., Botany Department, The University, Carlton, N.3 1949
Bage, Miss F., O.B.E., M.Sc., Grove Crescent, Toowong, Brisbane, S.W.1, Queensland 1906
Baker, A. A., 52 Carlisle Street, Preston, N.18 1946
Bishop, J. J., B.A., Northcote High School, St. George's Road, Northcote, N.16 .. 1950
Brazenor, C. W., National Museum, Russell Street, Melbourne, C.1 1931
Broadhurst, E., M.Sc., 457 St. Kilda Road, Melbourne, S.C.2 1930
Bryan, T. C., 17 Madden Street, Albert Park, S.C.6 1950
Buckle, G., B.Sc., 2 Ontario Street, Caulfield, S.E.7 1945
Butcher, A. D., M.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.1 1936
Butler, L. S. G., No. 3 Los Angeles Court, St. Kilda, S.2 1929
Canavan, F., B.Sc., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1936
Carlos, G. C., 262 Tucker Road, East Ormond, S.E.14 1951
Carter, A. A. C., "Fairholm," 15 Threadneedle Street, Balwyn, E.8 1927
Carter, A. N., Box 2, St. Ronan, 10 Berkeley Street, Hawthorn, E.2 1947
Chapman, Brigadier W. D., M.C.E., "Hellas," Stawell Street, Kew, E.4 1927
Chapple, Rev. E. H., The Manse, Warrigal Road, Oakleigh, S.E.12 1919
Clifford, H. T., B.Sc., Botany Department, The University, Carlton, N.3 1949
Clinton, H. F., "Whitehall," 20 Bank Place, Melbourne, C.1 1920
Cobbett, A. M., Flat 3, 137 Osborne Street, South Yarra, S.E.1 1951
Cochrane, G. W., M.Sc., Mines Department, Adelaide, South Australia 1945
Collins, A. C., 3 Lawrence Street, Newtown, Geelong 1928
Condon, M. A., M.Sc., 14 Blyth Street, Altona, W.18 1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot Road, Hawthorn, E.2 1919
Cookson, Miss I. C., D.Sc., 154 Power Street, Hawthorn, E.2 1919
Coulson, A., M.Sc., 23 Sheridan Avenue, Frankston 1929
Court, A. B., Childs Road, Kalorama 1949
Cowen, Miss Margot E. H., B.Agr.Sc., Department of Agriculture, Palmerston North, New Zealand 1936
Crespin, Miss I., B.A., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1919
Crohn, P. W., M.Sc., Mines Department, Melbourne, C.2 1946

Croll, I. C. H., M.Sc., 53 The Boulevard, Hawthorn, E.2 1934
Croll, R. D., B.Agr.Sc., 18 Russell Street, Camberwell, E.6 1940
Currey, D. T., 164 Ormond Road, Elwood, S.3 1948
Dadswell, Mrs. Inez W., M.Sc., 72 Florizel Street, Burwood, E.13 1939
Deane, Cedric, 461 St. Kilda Road, Melbourne, S.C.2 1923
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22 1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9 1946
Eadie, J. M., B.Sc., State Rivers and Water Supply Commission, 31 Flinders Lane, Melbourne, C.1 1949
Edwards, G. R., B.Sc., High School, Portland 1937
Elford, F. G., B.Sc., Dip.Ed., 76 New Street, Brighton, S.5 1929
Elford, H. S., B.E., c/o Tait Publishing Company, 349 Collins Street, Melbourne, C.1 1934
Esplan, W. A., 19 Retreat Road, Hampton, S.7 1951
Essame, J. C. L., B.A. (Camb.), Mines Department, Melbourne, C.2 1951
Fawcett, Miss Stella G. M., M.Sc., Botany Department, The University, Carlton, N.3 1937
Finlay, Miss C. J., B.Sc., Geology Department, University of Melbourne, Carlton, N.3. 1950
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7 1949
Forster, H. C., B.Agr.Sc., Ph.D., 6 Glendene Avenue, Kew, E.4 1938
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16 1933
Gaskin, A. J., M.Sc., Geology Department, The University, Carlton, N.3 1941
Gladwell, R. A., 79 Cochrane Street, Elsternwick, S.4 1938
Glenister, B. F., B.Sc., Geology Department, University of Melbourne, Carlton, N.3 .. 1950
Gordon, Alan, B.Sc., c/o C.S.I.R.O., Yarra Bank Road, South Melbourne, S.C.4 .. 1938
Gunson, Miss Mary, M.Sc., Zoology Department, The University, Carlton, N.3 1944
Hanks, W., 7 Lake Grove, Coburg, N.14 1930
Hardy, A. D., 24 Studley Avenue, Kew, E.4 1913
Hauser, H. B., M.Sc., Geology Department, The University, Carlton, N.3 1919
Haycraft, J. A., 27 Yeovil Road, Burwood, E.13 1951
Head, W. C. E., 7 Farmers Street, Nhill 1931
Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia 1935
Hill, R. D., D.Sc., Physics Department, University of Illinois, Urbana, Ill., U.S.A. .. 1946
Hitchcock, W. B., National Museum, Russell Street, Melbourne, C.1 1949
Hogan, T. W., M.Agr.Sc., 22 Cornell Street, Burwood, E.13 1947
Holland, R. A., 526 Toorak Road, Toorak, S.E.2 1931
Holmes, A. J., B.Sc., 606 Glenhuntly Road, Caulfield, S.E.8 1949
Holmes, W. M., M.A., B.Sc., 1 Balmoral Avenue, Kew, E.4 1913
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21 1934
Howe, Mrs. M. A., B.Sc., 10 Clyde Street, Thornbury, N.17 1948
Hutchinson, R. C., B.Sc., Department of Agriculture, Rabaul, New Guinea 1939
Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Agr.Sc., Botanical Gardens, South Yarra, S.E.1 1927
Jones, L. H. P., M.Sc., Ph.D., Chemistry Department, The University, Carlton, N.3 .. 1948
Kenley, P. R., B.Sc., 4 Anthony Street, Ormond, S.E.14 1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4 1942
Kilvington, T., M.Sc., Linden Farm, Upper Beaconsfield 1938
Langtry, J. O., 15 Boston Road, Balwyn, E.8 1950
Law, P. G., M.Sc., 10a Copelen Street, South Yarra, S.E.1 1946
Lindner, A. W., B.Sc., Bureau of Mineral Resources, Canberra, A.C.T. 1949
Lynch, D. D., 179 Park Street, Parkville, N.2 1950
McLennan, Assoc. Prof. Ethel, D.Sc., The University, Carlton, N.3 1915
McNally, J., B.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.3. 1950
MacPherson, Miss J. Hope, B.Sc., National Museum, Russell Street, Melbourne, C.1 .. 1940
Manning, N., 733 Punt Road, South Yarra, S.E.1 1940
Melhuish, T. D'A., M.Sc., c/o Elliots & Australian Drug Pty. Ltd., Terry Street, Rozelle, N.S.W. 1919
Mitchell, A. W. L., B.Sc., 71 Radnor Street, Camberwell, E.6 1946
Mitchell, Miss J., National Museum, Russell Street, Melbourne, C.1 1949
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9 1945
Morris, P. F., National Herbarium, South Yarra, S.E.1 1921
Moy, A. F., B.A., Melbourne Boys' High School, Forrest Hill, South Yarra, S.E.1 .. 1943
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, The University, Carlton, N.3 .. 1940
Nye, E. E., College of Pharmacy, 360 Swanston Street, Melbourne, C.1 1932
Oke, C., 34 Bourke Street, Melbourne, C.1 1922
Osborne, N., c/o Australasian Petroleum Company, Port Moresby, Papua 1930

Pike, Miss K. M., B.Sc., Botany Department, The University, Carlton, N.3 1948
Pinches, Mrs. M., 8 Thomas Street, Brunswick, N.10 1943
Pretty, R. B., M.Sc., 62 Glen Iris Road, Glen Iris, S.E.6 1922
Richardson, Sidney C., 16 Brewster Street, Essendon, W.5 1923
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5 1948
Samson, H. R., M.Sc., Industrial Chemistry Division, C.S.I.R.O., Box 4331, Melbourne, C.1 1945
Schleiger, N. W., B.Sc., "Elmhurst," Napier Street, White Hills, Bendigo 1949
Seeger, R. C., 56 Jenkins Street, Northcote, N.16 1946
Shaw, N. J., 192 Victoria Street, West Brunswick, N.12 1950
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W. 1918
Shipp, A., "Gangort," Canterbury Road, Heathmont 1946
Singleton, O. P., M.Sc., Geology Dept., University of Western Australia, Nedlands, W.A. 1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6 1932
Stubbs, G. C., M.Agr.Sc., Plant Research Laboratory, Swan Street, Burnley, E.1 .. 1943
Thomas, G. A., B.Sc., 39 Duffy Street, Ainslie, Canberra, A.C.T. 1944
Thomas, L. A., B.Sc., C.S.I.R.O., Stanthorpe, Queensland 1930
Threader, V. M., B.Sc., 63 Glenferrie Road, Kew, E.4 1950
Trüdinger, W., 27 Gerald Street, Murrumbeena, S.E.9 1918
Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R.O., Cronulla, N.S.W. 1936
Tugby, D. J., National Museum, Russell Street, Melbourne, C.1 1949
Vasey, G. H., B.C.E., The University, Carlton, N.3 1936
White, Miss Lillian, B.Sc., Royal Merchant Navy College, Bear Wood, Wokingham, Berks., England 1947
Whitehead, Mrs. Sylvia, M.Sc., 48 Invermay Grove, Rosanna 1942
Whitehead, R. C., B.Sc., 48 Invermay Grove, Rosanna 1948
Woodburn, Mrs. Fenton, 21 Bayview Crescent, Black Rock, S.9 1930
Wymond, A. P., M.Sc., Division of Forest Products, C.S.I.R.O., P.O. Box 18, South Melbourne, S.C.4 1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1950

The President and Council present to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1950.

The following meetings of the Society were held:

March 9th.—Annual Meeting. The following office-bearers were elected: *President,* Mr. P. Crosbie Morrison; *Vice-Presidents,* Professor J. S. Turner, Dr. F. L. Stillwell; *Honorary Treasurer,* Mr. R. T. M. Pescott; *Honorary Librarian,* Mr. F. A. Cudmore; *Honorary Secretary,* Dr. C. M. Tattam; *Members of Council,* Mr. V. G. Anderson, Associate Professor G. W. Leeper, Dr. J. S. Rogers, Dr. D. E. Thomas, Professor G. L. Wood.

The following *Members of Council* continued in office: Professor E. S. Hills, Professor L. H. Martin, Professor O. W. Tiegs, and all past Presidents.

The Annual Report and Financial Statement for 1949 were read and adopted.

At the close of the Annual Meeting an Ordinary Meeting was held. Lecture: "The Place of Ecology in the Modern World," by Mr. P. Crosbie Morrison.

April 13th.—Paper: "The Geology of the Lower Werribee River Valley," by M. A. Condon.

May 11th.—Paper: "Potential Evapotranspiration: A Simplification of Thornthwaite's Method," by A. A. Wilcock. Lecture: "Expedition to the Antarctic," by Dr. Fritz Loewe.

June 8th.—Lecture: "Biological Field Stations and National Parks Abroad," by Professor J. S. Turner.

July 13th.—Papers: "Revision of McCoy's Prodromus Types from the Lilydale and Killara Districts, Victoria," by Edmund D. Gill; "A Catalogue of Australian Tertiary Flora," by Suzanne L. Duigan (communicated by Professor J. S. Turner). Lecture: "Some Fossil Plants in the Brown Coal of Yallourn," by Dr. Isabel C. Cookson.

August 10th.—Exhibition of films: "Spermatogenesis of the Grasshopper," "The Phase-Contrast Microscope," arranged by Mr. J. J. McNeil.

September 14th.—Lecture: "Geophysical Methods in the Study of Continental Structure," by Professor J. Tuzo Wilson.

October 12th.—Special General Meeting. Amendments to the laws of the Society were submitted and adopted.

At the close of the Special General Meeting an Ordinary Meting was held. Lecture: "The Ecology of the Dandenong Range," by Mr. H. T. Clifford.

November 9th.—Lecture: "Stone Tools of the Australian Aborigine," by Mr. S. R. Mitchell.

December 14th.—"Further Studies in Victorian Chonetidae (Palaeozoic Brachiopoda)," by Edmund D. Gill. Lecture: "Cloud-Chamber and Photographic Plate Methods in the Detection of Elementary Particles," by Professor W. Gentner.

During the year nine members and nine associate members were elected. Three members and three associate members resigned. The total membership of the Society on December 31st was 245, an increase of nine for the year.

The Council deeply regrets the loss, by death, of three members.

Leslie Scott Latham, M.A., M.D., was born at Fitzroy on 13 June 1879. He was educated at Scotch College and the University of Melbourne, where he first completed an arts course in philology and classics in 1900. He then proceeded with medicine and in 1904 obtained the degrees of M.B., B.S. Both in arts and medicine he distinguished himself by winning several exhibitions and in 1907 he received the degree of M.D. After a brief period of general practice he became closely associated with St. Vincent's Hospital and took an active part in the high achievements in clinical medicine attained by that institution. He devoted considerable time to the administrative side of his profession, holding many offices. He was President of the Victorian Branch of the British Medical Association and President of the Royal Australasian College of Physicians, which office he held at the time of his death. With all these activities he still retained an abiding love for and lively interest in the classics and was an active member of the Classical Association. He served the University well, being Chairman of the Board of Stewart Lecturers in Medicine from 1921 to 1936, a Warden of Convocation, a Member of the Council, and Deputy Chancellor from 1946 to 1948. He became a member of the Society in 1946 and thereafter frequently attended the meetings. He died suddenly on 21 January 1950.

Gerald Carl Weigall, M.B., CH.B., was born in 1872 and educated at Melbourne Grammar School and the University of Melbourne. He took his M.B. degree in 1892 and Ch.B. the following year. He was appointed Resident Medical Officer at the Children's Hospital, and although he later went into private general practice he retained his association with this hospital for many years. He was President of the Melbourne Medical Association and of the Victorian Branch of the British Medical Association. In 1934 he was appointed Honorary Surgeon to His Royal Highness the Duke of Gloucester during his visit to this State in connection with the Melbourne Centenary celebrations. He became a member of this Society in 1945 and took considerable interest in its activities. He died on 22 February 1950.

Herbert Norman Warren was born in Melbourne on 6 April 1888. He entered the Commonwealth Public Service in 1914 and saw three years of service in the 1914-18 war. He was in the Electoral Branch for some years, holding several important posts, but later became Public Service Inspector for Tasmania. In 1938 he was posted to the Meteorological Branch as Assistant Director to guide its expansion called for by the demands of aviation and the Defence Services. He became Director in 1941. During the 1939-45 war he held the rank of Group Captain, R.A.A.F., and organized a highly efficient meteorological service for the armed services. In recent years he took a prominent part in international meteorology, being appointed Chairman of the Empire Conference of Meteorologists in London, 1946, and attended conferences of a similar kind at Toronto and Washington the following year. He was a member of the Executive Council of the International Meteorological Organization and President of the South-West Pacific Regional Commission of that body. While attending a meeting of that council at Lausanne he was taken seriously ill and although he recovered to

undertake the voyage home, he died on board ship at Adelaide on 5 August 1950. He had been a member of the Society since 1945.

The attendances at the Council meetings were as follows: Mr. Crosbie Morrison, 10; Mr. Anderson, 9; Mr. Baragwanath, 9; Mr. Casey, 9; Mr. Cudmore, 9; Captain Davis, 10; Professor Hills, 9; Associate Professor Leeper, 7; Professor Martin, 0; Mr. Pescott, 8; Dr. Rogers, 6; Professor Skeats, 8; Dr. Stillwell, 9; Dr. Summers, 2; Dr. Tattam, 10; Dr. Thomas, 7; Professor Tiegs, 5; Professor Turner, 5; Professor Wadham, 4; Professor Wood, 0.

Volumes and parts added to the library during the year numbered 1,950.

HONORARY TREASURER'S REPORT

The financial position of the Society gives cause for concern. The credit balance in the current account at 31 December 1950 was £359.7.7, compared with £676.8.6 at the corresponding date of 1949. This balance, however, is relatively inflated by the amount of £200 because the two State grants for the Government financial years 1949-50 and 1950-51 were paid into the Society's account during this one year. The reduced balance is accounted for mainly by the extremely high cost (£758) of the long overdue Volume 60 of the *Proceedings*. This amount will be offset to some extent by a grant from the University Publications Fund. It appears, however, that the credit balance will almost certainly be absorbed early in 1951, as payment for the printing of Volumes 59, part 2, and 62, part 2, will have to be made. The first of these publications, three years overdue, was recently distributed but the order for the required number had not been completed and the account had accordingly not been rendered. Volume 62, part 2, will be issued early in 1951. With long delays in publication overcome and with volumes once again appearing regularly and reasonably soon after the reading of papers, it is now only too clear that expenditure has in fact exceeded income over the past few years.

General costs of administration of the Society's affairs have risen but little over a long period of years. Certain essential charges are rising, but the chief reason for the steadily deteriorating financial position is the greatly increased cost of publication of the *Proceedings*, which is now more than double the pre-war figure and becoming still higher. The Society's income, determined in the first place on monetary standards which have over the past dozen years completely changed, is virtually static. What in the past was sufficient to allow publication of volumes often very much larger than those of the past few years, as well as to provide for binding of the leading periodicals and for upkeep of buildings and accumulation of reserve funds, now may be insufficient to provide for publication alone. Publication is by far the most important function of the Society, not only because of the direct value of the material published, but also because the growth of the library depends upon exchange of publications. A permanent lowering of the standard of the *Proceedings* might ultimately bring the Society to an end. The Council is not unmindful of this unfavourable state of affairs and is investigating possible means of overcoming it. At the same time it feels that members should be acquainted with the mounting difficulties which the Society will have to face in the near future. It may therefore be necessary, as has happened with other societies both in this country and overseas, to increase the membership dues.

FINANCIAL STATEMENT FOR YEAR ENDING 31 DECEMBER 1950

RECEIPTS

Balance in Bank at 1.1.1950		£676 8 6
Subscriptions—		
Members	£156 9 0	
Associate Members	81 18 0	
Country Members	13 13 0	
Arrears paid up	37 16 0	
Advance Subscriptions	3 3 0	
		292 19 0
Rents—		
Commonwealth Government	£204 0 0	
Field Naturalists Club	16 0 0	
Microscopical Society	12 0 0	
		232 0 0
Sale of Publications		171 14 3
Interest on Bonds		16 8 8
Grants and Donations—		
Government of Victoria	£400 0 0	
University of Melbourne	51 15 0	
Sundry Donations	6 16 6	
		458 11 6
Sundries		17 10
		£1848 19 9

EXPENDITURE

Printing—		
Proceedings, Vols. 60 and 62, pt. 1	£1116 14 9	
General	45 14 0	
		£1162 8 9
Salaries—		
Assistant Secretary	£24 0 0	
Assistant Librarian	12 0 0	
Assistant Editor	50 0 0	
Hallkeeper	12 0 0	
Gardener	28 2 0	
		126 2 0
Light, Water and Gas		21 7 0
Telephone		18 4 10
Rates and Taxes		6 13 4
Subscriptions, Books		36 1 6
Insurance		6 15 0
Petty Cash		6 10 0
Postage		54 10 4
Repairs and Replacements		35 5 3
Meetings		10 14 9
Fire Brigade		3 0 0
Sundries		1 19 5
Balance in Bank at 31.12.50		359 7 7
		£1848 19 9

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
16 February 1951.

S. M. WADHAM } *Hon.*
R. A. DUNN } *Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1.1.1950	£68 16 7	Balance at 31.12.1950	£70 3 9
Interest to 31.5.1950	1 7 2		
	£70 3 9		£70 3 9

LIFE MEMBERSHIP FUND

Balance at 1.1.1950	£171 18 2	Balance at 31.12.1950	£175 6 7
Interest to 31.5.1950	3 8 5		
	£175 6 7		£175 6 7

HOWITT MEMORIAL FUND

Balance at 1.1.1950	£121 5 1	Balance at 31.12.1950	£127 10 5
Interest on Bond	3 17 6		
Savings Bank Interest to 31.5.1950	2 7 10		
	£127 10 5		£127 10 5

T. S. HALL MEMORIAL FUND

Balance at 1.1.1950	£78 13 10	Balance at 31.1.1950	£80 5 0
Interest to 31.5.1950	1 11 2		
	£80 5 0		£80 5 0

BOOK-BINDING FUND

Balance at 1.1.1950	£112 11 4	Balance at 31.12.1950	£114 16 2
Interest to 31.5.1950	2 4 10		
	£114 16 2		£114 16 2

Accounts and Pass-books relating to each of the above Funds have been severally examined and found correct, and the Bank Certificate of Possession of Bonds amounting to five hundred pounds (£500), Savings Certificates to the face value of two hundred and fifty pounds (£250), and Fixed Deposit of two hundred pounds (£200) has also been inspected.

16 February 1951.

R. T. M. PESCOTT, *Hon. Treasurer.*

S. M. WADHAM } *Hon.*
R. A. DUNN } *Auditors.*

INDEX

New genera and species marked *

Brown, Prior, Anderson Pty. Ltd., Melbourne, C.1.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF VICTORIA

NEW SERIES

VOLUME 64

ROYAL SOCIETY'S HALL

9 VICTORIA STREET, MELBOURNE, C.1

1952-3

CONTENTS OF VOLUME 64

PART 1 (27 May 1952)

PART 2 (26 May 1953)

Papers read before the Society during 1951 and edited under the authority of the Council. The authors of the several papers are individually responsible for the accuracy of the statements made and the soundness of the opinions given therein.

Brown, Prior, Anderson Pty. Ltd., 430 Little Bourke Street, Melbourne

Fig. 1 (Upper).—Colony of *P. claviforme* Bainier, on Czapek agar, showing two types of coremia.
Fig. 2 (Lower).—Pattern of sporing head, showing the short quadrangular columns of spores radiating out in an umbel-like way (from an old malt slope).

NOTE ON THE SPINES OF A TERTIARY ECHINOID FROM VICTORIA

By Edmund D. Gill, B.A., B.D.*

[Read 12 July 1951]

Summary

A specimen of the Miocene echinoid *Linthia nelsoni* (McCoy) with spines attached has been found, and the spines are now described. They appear to possess taxonomic value.

Introduction

When marine animals die, their skeletons become sedimentary materials which usually suffer movement before they come to rest in the positions in which we find them in the rocks (thanatocoenoses). Such movement, even though slight, is enough to rob echinoids of their spines, and thus it is rare for fossil echinoids to be discovered with their spines attached.

The Miocene limestones of Victoria were laid down in waters not very distant from the land, but nevertheless they contain but a comparatively small percentage of terrigenous material. On the whole, therefore, sedimentation was not rapid, and sudden burial of faunules was unusual. However, by some rare chance a specimen of *Linthia nelsoni* (McCoy 1882) has been preserved which moved so little and was covered so quickly that the spines can be seen adhering still to the surface of the test.

Genus **Linthia** Desor 1853

Species **Linthia nelsoni** (McCoy)

Figure 1.

Pericosmus nelsoni McCoy 1882, Prodromus of the Palaeontology of Victoria, Dec. 7, *Geol. Surv. Vic.*, pp. 17-19, Pl. 66, figs. 1-2, Pl. 67, fig. 1.

Type Specimens

1. Syntypes. McCoy figured three specimens, but did not select any one as a holotype, so the three are syntypes. There is no outstanding specimen which could be selected as a holotype, and indeed all three are quite imperfect. Although McCoy's figures give a fairly satisfactory idea of the species, they involve considerable reconstruction. The syntypes are in the National Museum, and are identified as follows:

*Palaeontologist, National Museum.

McCoy's figure	*Nat. Mus. reg. no.*	*Other Information*
Plate 66, figures 1, 1a, 1b	P 12211	'From Rev. Mr. Price, Waurn Ponds, 28/7/77.' (Donor's name not clear.)
Plate 66, figure 2	P 12212	'Presented by Wm. Nelson, Esq., Waurn Ponds, 7/6/80.'
Plate 66, figure 2a	P 12213	'Ad 26' (Geol. Surv. locality number.)
Plate 67, figures 1, 1a, 1b	P 12211	See below.

There appears to be an error in McCoy's description of his plates. He says that Pl. 76, fig. 1, is one specimen, fig. 2 is 'another specimen', and Pl. 67, fig. 1, is yet 'another specimen'. This makes three specimens in all, and according to Museum records there were only three types. However, on comparing the specimens with the figures, it is clear that three different ones are figured in Plate 66, as shown in the table above. Apparently Pl. 67, fig. 1, is a reconstruction of the same specimen as figured in Pl. 66, fig. 1, viz. 12211. The profile agrees with that of this fossil, but as with all the rest, the drawing is a reconstruction.

All three syntypes come from the limestone quarry on the south side of the Princes Highway at Waurn Ponds, west of Geelong, Victoria. It is the Geological Survey locality Ad 26, which is described as 'Quarry on reserve opposite old "Victoria Inn", Colac Road, 5½ miles from the Barwon Bridge.' The quarry is shown on Quarter Sheet 28 NE, and on the Military Map of the area.

2. Hypotype. The specimen with the spines described below was collected by Dr. G. B. Pritchard from the same Waurn Ponds quarry as the syntypes, and when his collection was acquired by the Museum, he kindly drew my attention to this unique specimen and suggested a note be prepared upon it. The fossil is now Nat. Mus. reg. no. P 15277.

Description of Spines

In his description of *Linthia nelsoni,* McCoy stated 'Spines on under side slender, striated longitudinally, about 4 lines long.' There are no spines attached to the tests but a few occur in the matrix, and it seems McCoy surmised that these belonged to the species.

The primary spines are short, about half a centimetre long, with a smooth base of truncated cone shape, the condyle or acetabulum occupying what would otherwise be the apex of the cone. The shaft is circular in cross-section, about half a millimetre in diameter, and apart from a slight expansion where it meets the base, tapers little or not at all until at the distal end it is rounded (see fig. 1a). The shaft

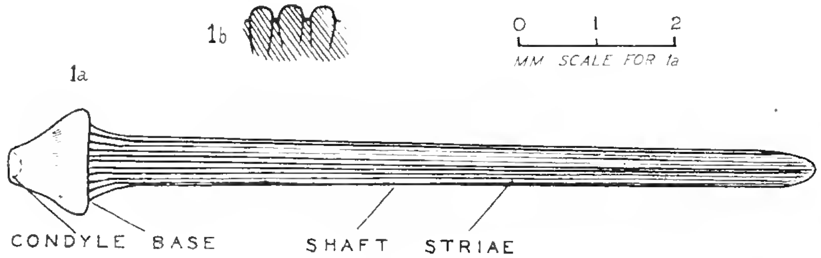

Fig. 1. Spine of *Linthia nelsoni* (McCoy).
1a. General proportions of spine. 1b. Cross-section of striae, greatly enlarged.

possesses about 21 longitudinal striae which run its full length. Two attempts to grind cross-sections mounted in Canada balsam and paraffin respectively were unsuccessful owing to the highly brittle character of the recrystallized calcite. However, a fragment mounted to show a natural cross-section indicated that the striae have a cross-section like that shown in fig. 1b. The striae continue down like segments into the material of the shaft. No orifice is present in these fossil spines.

Taxonomic Value

Among the echinoids collected by Dr. Pritchard there is one poorly preserved specimen (Nat. Mus. reg. no. P 15278) which suggests *Linthia nelsoni,* but does not exhibit sufficient structure to make a sound determination possible. However, it possesses a few spines, and they are precisely like those on specimen P 15277, so one can assume with some confidence that it belongs to McCoy's species.

On the other hand, in the Cudmore Collection in the National Museum there is a *Linthia* from the New Quarry, Batesford, Victoria, which has spines, and was collected by Mr. F. A. Cudmore in 1946. Previous to the arrival of the Pritchard specimens, this was the only irregular fossil echinoid with spines which Mr. Cudmore had seen, in spite of his wide experience as a collector. Mr. Cudmore's specimen belongs to a flatter species of *Linthia*, and although similar, the spines differ in length, in the greater number of striae on the shaft, and in the shape of the base. Thus different kinds of *Linthia* are shown to have similar and yet quite distinct types of spines. It seems, therefore, that the spines of these fossils have taxonomic value (as has been proved for other echinoids) and it should be possible in future to recognize the presence of *Linthia nelsoni* in our Victorian rocks by the presence of their spines alone.

2

VICTORIAN MUSCI

PART 1: INTRODUCTION AND ANDREAEACEAE

By H. T. CLIFFORD, M.Sc.*

[Read 12 July 1951]

Abstract

The study of mosses in Victoria has been long neglected. In this introductory paper some of the problems involved are discussed and a summary of the literature is set forth. The genus Andreaea is treated in detail both as to its synonymy and distribution.

Introduction

For the student of Victorian mosses there are many difficulties. No handbook is available and the few published lists are both incomplete and unreliable. Since their publication, several generic concepts have changed, and many species are now placed in other genera. This, and the fact that they contain much unindicated synonymy, reduces the value of these older lists.

The most important check-list is the 'Census Muscorum Australiensum' (Watts and Whitelegge, 1902, 1905). Unfortunately this census deals only with the acrocarpous mosses as then known for Australia. The list gives the specific name, the author responsible, the periodical in which the species was described, and certain of the localities from which it had been collected. For the pleurocarpous mosses, we must turn to an old and incomplete list of Australian mosses by Mitten (1883), who prepared a table of all the mosses known by him to come from Australia. An earlier, apparently neglected, article by Muller and Hampe (1853) records several pleurocarpous mosses not enumerated by Mitten. Recently Sainsbury (1946, 1948) and Clifford and Willis (1951) have recorded additional species for the flora. By combining all these records, a reasonably reliable check-list for the State can be prepared.

A check-list is of limited value unless literature is available which will enable species and genera to be determined. The following books and articles are useful references. The best available work for south-eastern Australia is the revision of the New Zealand flora by Dixon (1913-28). Most of the plants described therein are common to both regions. Rodway (1914) has provided a manual for the Tasmanian mosses, and this includes most of the Victorian species. The 'Handbook of the New Zealand Flora' by Hooker (1867) has a good key to the genera. Unfortunately neither of these references is illustrated, but they can be supplemented with the 'Flora Novae-Zelandiae' (Hooker 1855) and the 'Flora Tasmaniae' (Hooker 1860), both of which contain excellent plates. In addition, there is a semi-pictorial key to the Tasmanian mosses (Bastow 1886) and a book of plates by Mueller (1864). The most complete reference is the moss volume of the Pflanzenfamilien (Brotherus 1904). It provides a key to the moss families of the world, keys to the genera and partial keys to the species. Although very complete, the key to the families is very difficult and needs careful interpretation. In the second revised edition (Brotherus 1924-25) there is no key to the families.

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Assuming that by these means a species is determined, there is still the problem of whether it is correctly named by present standards. In the interval that has elapsed since the books referred to were written, many alterations have taken place in the delimitation of genera, as is illustrated in Table 1 where the synonyms of *Catagonium politum* (Hk. et W.) Dus. are set out.

The tracing of a species whose specific epithet remains constant is easier than tracing one that goes into synonymy with another species. With the latter situation, only an extensive knowledge of the literature and access to type specimens will solve the problem. Large numbers of synonyms were created in the nineteenth century by bryologists who did not realize the wide distribution and variability of the plants with which they were dealing. In Table 2 the synonymy of *Bryum dichotomum* Hedw. is set out to illustrate this point.

TABLE 1

Synonyms of Catagonium politum *(Hk. et W.) Dus.*

Species	Reference
Hypnum politum Hk. et W.	Hooker 1867
Acroceratium politum (Hk. et W.) Mitt.	Mitten 1883
Catagonium politum (Hk. et W.) Dus.	Rodway 1914
Eucatagonium politum (Hk. et W.) Broth.	Brotherus 1925

In addition to the general literature mentioned, there are several papers dealing with the systematics of particular groups. Watts (1918) has discussed the Australian species of the genus *Sphagnum*, and Sainsbury in a series of articles in the 'Victorian Naturalist' between April 1932 (vol. 48) and August 1932 (vol. 49) discusses and describes in detail several species. Monographs are available for the genus *Zygodon* (Malta 1923), *Ulota* (Malta 1933) and *Dawsonia* (Burges 1949).

As well as articles concerning systematics there are a few that discuss the cryptogams of selected localities or mention the mosses as constituents of local floras. The best of these papers is by Stirling (1885), who dealt with the cryptogams of the Australian Alps. Others who have published lists are Bastow (1904, '05), Beauglehole (1947), Garnet and Willis (1949), Leslie (1924, '25), Morris (1929), Murdoch (1910), Sullivan (1887), Watts (1905), and Willis (1947).

It is obvious from the foregoing remarks that the moss flora of the State is in need of revision, a task upon which the writer is at present engaged. Every genus must be revised and a full description prepared for each of the species. The time involved will be great, and so it is intended that Part 2 of this series will be a check--list with the nomenclature revised and the synonymy where possible unravelled. In Part 3 the distribution of the mosses within Victoria will be discussed.

TABLE 2

The synonymy of Bryum dichotomum *Hedw. as it concerns Victorian species*

Species	Synonym
Bryum dichotomum Hedw.	*Bryum gambierense* C.M.
	B. cupulatum C.M.
	B. pachytheca C.M.
	B. pachythecoides C.M.
	B. pachypyxis C.M.
	B. subacnum C.M. et Hpe.
	B. sullivani C.M.
	B. annulatum Hk. et W.

Andreaeaceae

The species of *Andreaea* are dark, varying from black or dark olive-green to red or reddish-brown; only the youngest leaves show the presence of chlorophyll. The older leaves are invariably reddish-brown when viewed with transmitted light as when examined under the microscope. In the upper portion of the leaf the cells are rounded or slightly angular, but towards the leaf base they are rectangular with sinuose walls. Little significance can be placed upon the papillosity of the cell wall, because it is very variable. The capsule is elevated not upon a seta but a pseudopodium, a structure morphologically resembling a seta. There is no peristome, the capsule opening along four valves separated by vertical slits. The valves may be united at their tips but are rarely found in this condition. A columella is present and persists in the mature capsule.

As with many other mosses the genus *Andreaea* has a characteristic habitat. From the descriptions in the standard floras, an impression is gained that *Andreaea* species grow 'in tufts or cushions on non-calcareous rocks of mountainous or frigid zones' (Sharpe 1936). Brotherus (1924) adds that in the arctic regions the genus may grow upon the earth. Until recently it was presumed that the Victorian members of the genus occupied habitats in keeping with this description. Plants have been collected from the Australian Alps and Mount Wellington (Watts and Whitelegge 1902). Both localities are about 5000 ft. and are locally regarded as alpine or sub-alpine.

Within the last two years collectors have gathered plants of the genus from the low altitude of approximately 2000 ft. In each instance the habitat was sandstone rocks within dry sclerophyllous forests. The localities are hot and dry in summer, whilst in winter, although frosts are common, snow falls are rare. Such a habitat is not in agreement with that given in the standard floras, most of which were written in the northern hemisphere. Were it not for Rodway's notes on the Tasmanian mosses (1914) it might be thought that the descriptions of the habitat from northern latitudes did not apply in southern latitudes. But Victoria is not the only place where this seemingly atypical behaviour is found, for the type collection of *A. subulata* Harv. (1840) was from the top of Table Mountain, South Africa, where the summers are also hot and dry.

Certain of the synonyms and the local distributions of the Victorian species are set out in Table 3. Three species are recorded for the State, but none is endemic. According to Martin (1946), *A. rupestris* Hedw. is cosmopolitan, *A. subulata* Harv. is circumpolar in the southern hemisphere, and *A. australis* Mitt. is restricted to Australia, Tasmania and New Zealand. On the Australian mainland these three species are also found in New South Wales. The genus has not yet been recorded from any of the other States.

Table 3

The distribution and synonymy of the Victorian species of the genus Andreaea

Species	Synonymy	Localities
A. rupestris Hedw.	*A. asperula* Mitt. *A. petrophila* Ehrh. *A. muelleri* Sond. *A. julicaulis* C.M.	Bogong High Plains Cathedral Range Grampians Mount Buffalo Mount Macedon Baw Baws Mount Kaye

A. australis Mitt.		Mount Wellington
A. subulata Harv.	*A. subulatissima* C.M.	Bogong High Plains Grampians Mount Buffalo Baw Baws

Description of Species

Andreaea rupestris Hedw. Spec. Muscorum 1801.

Syns.: *A. petrophila* Ehrh. in Hann. Mag., 1784; *A. asperula* Mitt., Journ. Linn. Soc., vol. 4, 1860; *A. muelleri* Sond., apparently a ms. name; *A. julicaulis*, C. M. Hedwigia, vol. 37, 1898.

The size of the plants (Figs. 3, 3a, 4) is variable from a few mm. to several cm. tall, either densely caespitose or laxly procumbent; sparingly branched. The leaves are concave, ovate to ovate-lanceolate; leaf tip obtuse or accasionally acute. Towards the ends of the branches the leaves are falcato-secund. Nerve absent. Perichaetial leaves differentiated, convolute, obtuse or with a short apiculus.

The writer has suggested that *A. asperula* Mitt. is a synonym of *A. rupestris* Hedw. because after examining a portion of the collection from which the species was named he can see no differences that exclude it from the latter species. However, no absolute decision can be made until Mitten's herbarium is examined, for there may be another plant mixed in with the portion sent to him.

Andreaea australis Mitt. Jour. Bot., vol. 8, 1856.

In habitat *A. australis* Mitt. (Figs. 2, 2a) resembles robust forms of *A. rupestris* Hedw., but differs from that species in possessing a well developed nerve to the leaf and only slightly differentiated perichaetial leaves. The species is imperfectly known in Victoria, having been collected only by Mueller, F. von, who gathered the material from which the type description was prepared.

Andreaea subulata Harv. Icones Plantarum, vol. 3, 1840.

Syn.: *A. subulatissima*, C. M. Hedwigia, vol. 37, 1898.

A. subulata Harv. (Figs.1, 1a) has a habit similar to the previous species but its leaves are quite a different shape. They are broad at the base and contract sharply to a narrow subula. The subula is almost wholly made up of nerve and was described originally as nerveless. At the base of the leaf the nerve is quite conspicuous. The perichaetial leaves are strongly differentiated, convolute, and obtuse or rarely acute.

KEY TO SPECIES

Leaves ligulate, contracting from a broad base	*A. subulata*
Leaves ovate or ovate-lanceolate	A.
A. Leaves nerveless	*A. rupestris*
Leaves nerved	*A. australis*

Acknowledgments

It is a pleasure to acknowledge the kindness of Mr. A. W. Jessep, Director of the National Herbarium, Melbourne, for making available the collections in his charge, and to thank Dr. E. I. McLennan for her helpful encouragement during the preparation of this paper.

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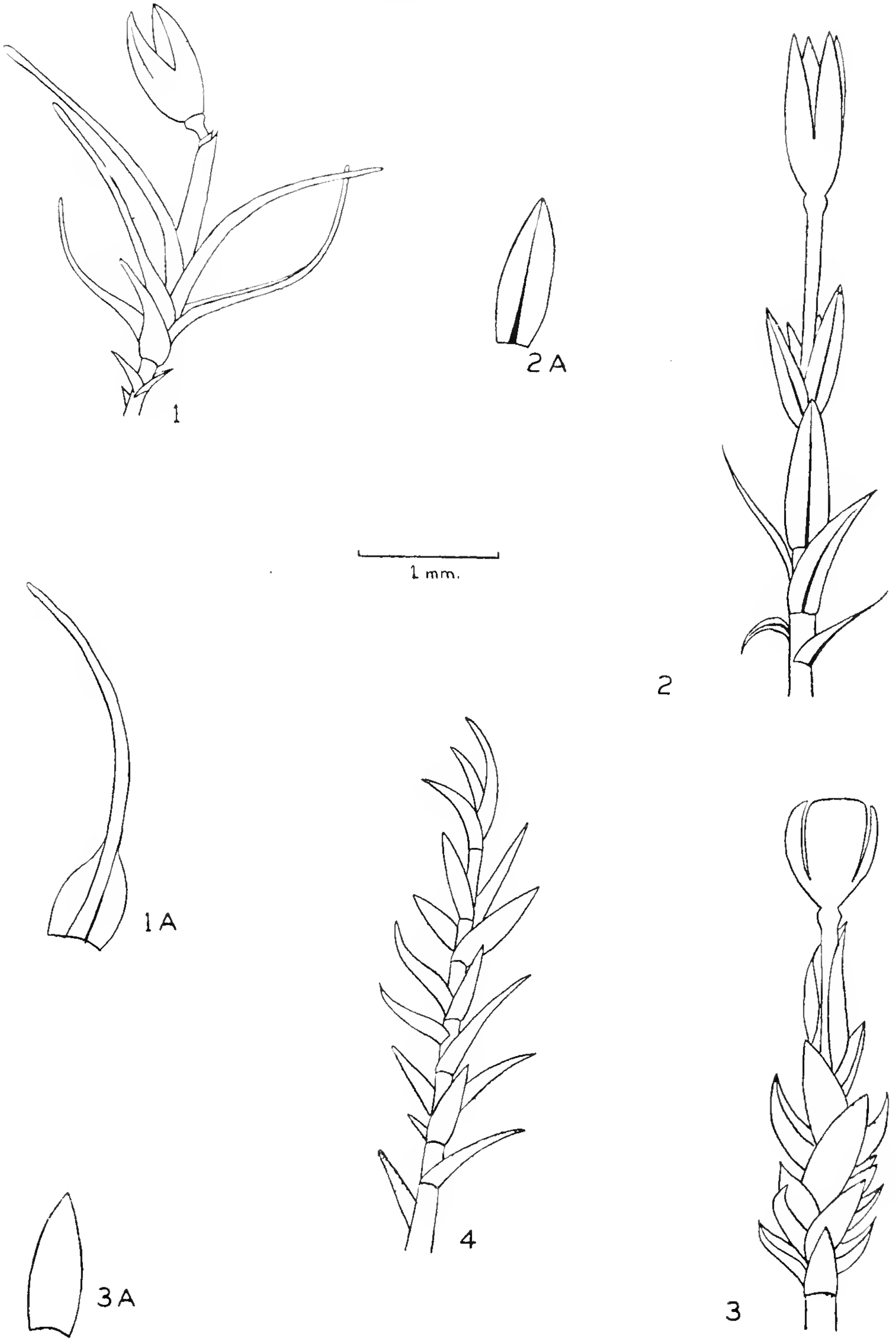

Fig. 1—Typical plant of *A. subulata* Harv. Fig. 1a—Leaf of *A. subulata* Harv.
Fig. 2—Typical plant of *A. australis* Mitt. Fig. 2a—Leaf of *A. Australis* Mitt.
Fig. 3—Erect form of *A. rupestris* Hedw. Fig. 3a—Leaf of erect form of *A. rupestris* Hedw.
Fig. 4—Procumbent form of *A. rupestris* Hedw.

3

THE DESCRIPTION AND DISTRIBUTION OF THE SPECIES OF *PENICILLIUM* Link IN SOME VICTORIAN SOILS

By E. I. McLennan and S. C. Ducker

[Read 12 July 1951]

Summary

The genus *Penicillium* is a dominant one in the micro-flora of soils. An account of this genus as it occurs in some Victorian soils has been presented. Forty-five species have been identified and their distribution in some sandy podsols (acid) and Mallee soil (alkaline) has been noted. The majority of the species belong to two sections of the genus, the *Monoverticillata* and the *Asymmetrica-divaricata*. A number of the strains were tested for possible antibiotic properties.

The cultural and microscopical characters of the forty-five species have been described and their chief diagnostic characters have been stressed. The descriptions are illustrated by line sketches and dichotomous keys have been drawn up to aid in identification.

Introduction

There are many records of genera and species of fungi that have been isolated from soils of the Northern Hemisphere. Although there are only a few records for the Southern Hemisphere, it has been recognized (Burges 1939) that the genera of mould fungi occurring in soil show no marked geographical limits, and that they represent a very uniform flora. The species of *Penicillium* are the commonest constituents of this flora; we have, however, little accurate information about those species of this genus which are normally present in soil, and practically none about their vertical distribution in this environment.

During a study of the fungal micro-flora of some Victorian (Australian) soils, we have isolated and studied those *Penicillium* species that appeared on Czapek and malt agar dilution plates (James and Sutherland 1939). The greater number of isolations has been obtained from a sandy podsol which supports a characteristic heath vegetation, and which occurs close to the southern coast of this State. Some of the characteristic features of this podsol are summarised in Table 1.

Table 1

Horizon	A_1	A_2	B 'coffee rock'	C
Average depth	0-18 in.	18-34 in.	34-38 in.	38 in.
Colour	medium grey	light grey	dark brown	yellowish
pH	4·6	5·2	4·8	5·2
Organic carbon	1·47	0·28	1·34	—

Penicillium species were isolated also from the Mallee soils, which have an alkaline profile throughout, as well as from loam from the alpine regions of the Bogong High Plains, Victoria.

Methods

All *Penicillium* species were sub-cultured from the dilution plates of malt agar to malt slopes, and these formed the reservoir of material for this study. If bacterial contamination occurred, the colonies were cleaned by the accepted methods, and frequently single spore isolations were made.

The fungi were plated out on to three media—malt, Czapek-Dox, and Raulin-Thom agar, made according to the following formulae:

Malt extract agar

malt extract	25·0 gm.
agar	18·0 ,,
distilled water	1000 ml.

Later, malt agar as prepared by Raper and Thom (1949) was used:

malt extract	20·0 gm.
dextrose	20·0 ,,
peptone	1·0 ,,
agar	25·0 ,,
distilled water	1000 ml.

Czapek-Dox agar

sucrose	30·0 gm.
sodium nitrate ($NaNO_3$)	3·0 ,,
monopotassium di-hydrogen phosphate (KH_2PO_4)	1·0 ,,
magnesium sulphate ($MgSO_4.7H_2O$)	0·5 ,,
potassium chloride (KCl)	0·5 ,,
ferrous sulphate ($FeSO_4.7H_2O$)	0·01 ,,
agar	18 ,,
water to	1000 ml.

pH adjusted to 6·9-7·0 with NaOH.

Raulin-Thom agar

sucrose	70·00 gm.
tartaric acid	4·00 ,,
ammonium tartrate	4·00 ,,
ammonium phosphate	0·60 ,,
potassium carbonate	0·60 ,,
magnesium carbonate	0·40 ,,
ammonium sulphate	0·25 ,,
zinc sulphate	0·07 ,,
iron sulphate	0·07 ,,
potassium silicate	0·07 ,,
agar	27 ,,
water to	1500 ml.

The mode of preparation was that set out by Smith (1946). The initial pH lay between 3·8-3·9 and was adjusted to 6·9-7·0 with KOH.

The inoculum for the plates was prepared by cutting an approximate sq. cm. from a colony grown for 14 days on malt agar at 24° C. This was transferred to a tube containing 9 ml. of sterile water. After vigorous shaking a platinum loop

(diam. 2 mm.) was inserted and a loopful of the spore suspension was transferred to the centre of each plate. The plates were incubated in the dark for seven days at 24° C. and then for seven days in the light at room temperature.

The Species of Penicillium Isolated

Forty-five species have been isolated from the various soils; approximately half this number belong to the *Monoverticillata* and the *Asymmetrica-divaricata* series, as the following list indicates.

MONOVERTICILLATA (12 species)

Adametzi, fellutanum, frequentans, fuscum, lapidosum, lividum, purpurrescens, pusillum, restrictum, spinulosum, Thomii, vinaceum.

ASYMMETRICA-DIVARICATA (11 species)

albidum, canescens, Godlewskii, janthinellum, Kapuscinskii, lilacinum, Melinii, nigricans, piscarium, Raciborskii, Rolfsii.

FASCICULATA (8 species)

claviforme, expansum, Gladioli, granulatum, Martensii, puberulum, Urticae, viridicatum.

BI-VERTICILLATA-SYMMETRICA (7 species)

diversum, funiculosum, islandicum, purpurogeneum, rubrum, rugulosum, verruculosum.

ASYMMETRICA-VELUTINA (3 species)

chrysogenum, digitatum, meleagrinum.

MONOVERTICILLATA-RAMIGENA (2 species)

cyaneum, Waksmani.

ASYMMETRICA-LANATA (1)

lanosum.

BREVI-COMPACTUM (1)

brevi-compactum.

We have included in our descriptions *Aspergillus Sydowi* (Bain. and Sart.) Thom and Church, and two strains of *Scopulariopsis brevicaulis* (Sacc.) Bainier.

The occurrence of the *Penicillium* species in the soils examined and their vertical distribution are shown in Table 2.

Burges (1950) has shown that fungus spores with a mucilaginous coat are washed downwards through a sandy soil, but spores which are dry and powdery showed 'practically no downward movement in sand.' Spores of *Penicillium* are of this dry type; indeed Burges includes *Penicillium cyclopium* among the fungi he used in his experiments and he states: 'In fungi such as *Penicillium* which produce dry spores, there is little likelihood of the spores being washed to lower levels.' The vertical distribution of the various species of this genus noted in Table 2 represents therefore their actual distribution in the soils examined.

The most abundant species in the A horizon of the sandy podsols are *P. Adametzi, janthinellum, nigricans, restrictum, spinulosum* and *verruculosum*; the

TABLE 2

Species	Soil type	Sandy podsol			Mountain loam						Mallee				Litter, from sandy podsol, Frankston							
	Locality	Frankston			Bogong High Plains						Mildura				Species (see note)							
					Pretty Valley			Box Plot														
	Horizon	A	B	C	A	B	C	A	B	C	6-8 in.	12-18 in.	28-35 in.	70 in.	L.v.	E.	R.	H.	L.m.	B.	C.	
Aspergillus Sydowi					+	+																2
P. Adametzi		+	+	+							+	+					+	+	+			8
P. albidum												+										1
P. brevicompactum			+								+											2
P. canescens																				+		1
P. chrysogenum			+	+																		2
P. claviforme																			+	+		2
P. cyaneum		+			+											+						3
P. digitatum		+									+											2
P. diversum			+																			1
P. expansum			+	+							+											3
P. fellutanum			+																			1
P. frequentans			+	+		+											+					4
P. funiculosum		+		+		+	+	+														5
P. fuscum									+													1
P. Gladioli											+	+										2
P. Godlewskii		+	+													+						3
P. granulatum		+																				1
P. islandicum		+																				1
P. janthinellum		+	+	+																		3
P. Kapuscinskii											+											1
P. lanosum					+	+			+													3
P. lapidosum																			+	+		2
P. lilacinum													+									1
P. lividum													+									1
P. Martensii				+								+										2
P. meleagrinum			+													+						2

Continued

Species	Soil type	Sandy podsol			Mountain loam						Mallee				Litter from sandy podsol, Frankston							
	Locality	Frankston			Bogong High Plains						Mildura				Species (see note)							
					Pretty Valley			Box Plot														
	Horizon	A	B	C	A	B	C	A	B	C	6-8 in.	12-18 in.	28-35 in.	70 in.	L.v.	E.	R.	H.	L.m.	B.	C.	
P. Melinii		+		+																		2
P. nigricans		+	+	+	+	+					+					+						7
P. piscarium			+																			1
P. puberulum				+																		1
P. purpurogenum			+				+					+										3
P. purpurrescens		+																				1
P. pusillum																			+	+		2
P. Raciborskii			+																			1
P. restrictum		+	+	+					+							+		+				6
P. Rolfsii																			+	+		2
P. rubrum				+																		1
P. rugulosum		+																				1
P. spinulosum		+	+									+										3
P. Thomii																			+	+	+	3
P. Urticæ																			+			1
P. verruculosum		+	+											+	+							4
P. vinaceum											+											1
P. viridicatum			+																			1
P. Waksmani		+												+	+	+	+		+			6
Scopulariopsis brevicaulis		+			+																	2
		17	18	12	5	5	2	1	3		8	6	2	2	2	6	3	2	8	6	1	

NOTE.—The species of flowering plants on the sandy podsol from the litter of which fungal species were isolated, are as follows:—

L.v.—*Leucopogon viragtus* R. Br.

E.—*Epacris impressa* Labill.

R.—*Ricinocarpus pinifolius* Desf.

H.—*Hibbertia sericea* R. Br.

L.m.—*Leptospermum myrsinoides* Schlech.

B.—*Banksia marginata* Cav.

C.—*Casuarina distyla* Vant.

first four of these were repeatedly isolated from the three horizons of this podsol. The last two did not extend deeper than the B horizon.

Ten species were restricted to the 'coffee rock' or deeper—*P. brevi-compactum, chrysogenum, diversum, expansum, fellutanum, frequentans, meleagrinum, piscarium, Raciborskii* and *viridicatum*.

Four species were restricted to the C horizon—*P. puberulum, Martensii, purpurogeneum* and *rubrum*.

The sclerote-forming species were isolated only from the sparse litter which collects under the various plants characteristic of the heath vegetation growing on this soil. The sclerotes appear to withstand the hot and dry summer conditions which prevail in these regions.

Of the fifteen species recovered from the Mallee soils, four were restricted to this habitat. The more alkaline conditions were characterized by the appearance of *P. albidum, Gladioli, lilacinum* and *lividum*.

Many of the isolations were tested for possible antibiotic properties. The test organisms used were *Staphylococcus aureus* and *Bacterium coli*. Nutrient agar plates were seeded with 3 ml. of similar agar which had previously been inoculated with the test organism in a concentration of 1 ml. of a 24-hour broth culture in 100 ml. of agar. With a sterile cork borer, discs of 7·5 mm. diameter were cut from the periphery of a 7-day-old culture on malt agar of the *Penicillium* to be tested. These discs were placed on the seeded plates, which were then incubated at 37° C. for 24 hours. The results obtained are shown in Table 3.

TABLE 3

	B. coli	*S. aureus*			*B. coli*	*S. aureus*	
P. Adametzi	—	—		*P. Melinii*	—	—	
P. chrysogenum	—	+		*P. nigricans*	—	+	some strains
P. cyaneum	—	—		*P. piscarium*	—	+	
P. expansum	—	—		*P. puberulum*	—	—	
P. fellutanum	—	+		*P. purpurogenum*	—	—	
P. frequentans	—	—		*P. Raciborskii*	—	+	
P. Godlewskii	—	—		*P. restrictum*	—	+	some strains
P. granulatum	—	—		*P. rubrum*	+	+	
P. janthinellum	—	+	some strains	*P. rugulosum*	—	+	
P. lanosum	—	+		*P. spinulosum*	—	—	
P. lilacinum	—	—		*P. verruculosum*	—	—	
P. Martensii	—	+		*P. viridicatum*	—	+	
P. meleagrinum	—	+		*P. Waksmani*	—	—	

Only seven species of *Penicillium* have previously been recorded for Australia (Brittlebank 1937-1940). They are:

(1) *Penicillium bicolor* Fr. According to Raper and Thom (1949), this name is probably based on a coremium-forming member of the *Biverticellata-Symmetrica* and is not accepted by them as a valid species.

(2) *Penicillium candidum* Link. 'This is probably synonymous with *P. caseicolum* Bainier or some white mutant.' (Raper and Thom 1949.)

(3) *Penicillium expansum* Link.

(4) *Penicillium Gladioli* Machacek.

(5) *Penicillium glaucum* Link. 'Frequently used for any green *Penicillium*, no one knows what form was described by Link.' (Raper and Thom 1949.)

(6) *Penicillium italicum* Wehner.

(7) *Penicillium roseum* Link. Probably synonymous with *Gliocladium roseum* (Link?) Bainier.

THE MONOVERTICILLATA

Key to Monoverticillata

1.	Sclerotes present	2.
1.	Sclerotes absent	3.
2.	Sclerotes formed on malt, Czapek and Raulin agars, giving a characteristic surface colour to the colony	*P. lapidosum*
2.	Sclerotes present and readily visible on malt and Raulin agar (at least in fresh isolations), but not on Czapek agar	*P. Thomii*
2.	Sclerotes present, but not visible on the green surface of the colony, as they are embedded in the mycelial felt	*P. pusillum*
3.	Surface velvety (or at most sparsely floccose); ropes of hyphae absent	4.
3.	Surface floccose or lanose; ropes of hyphae absent	5.
3.	Surface mealy, floccose or lanose; ropes of hyphae present	9.
4.	Spores globose, spiny; colony reverse pale on all three media ..	*P. spinulosum*
4.	Spores globose, conspicuously spiny; colony reverse on Czapek and Raulin in purplish-brown shades; odour fetid	*P. purpurrescens*
4.	Spores globose, mainly smooth; colony reverse on all three media in yellow to brown shades	*P. frequentans*
5.	Growth restricted on all three media—at 14 days averaging 2·5-3 cm. or less	6.
5.	Growth restricted on Czapek but not on malt or Raulin agars ..	7.
5.	Growth not restricted on any media	8.
6.	Spores sub-globose, smooth; sporing surface pea-green	*P. fellutanum*
6.	Spores globose, 2 μ diam., rough	*P. restrictum*
6.	Spores globose, 4-4·5 μ diam., rough	*P. fuscum*
7.	Colony diameter on malt and Raulin agar (6-7 cm.) twice that on Czapek agar (2-3 cm.); spores globose, 3-4 μ, rough	*Aspergillus Sydowi*
8.	Growth not restricted on any of the three media; sporing colour deep greyish-blue	*P. lividum*
9.	Growth restricted on all three media (2-2·5 cm. in 14 days); deep red exudate drops give a characteristic appearance to the surface ..	*P. vinaceum*
9.	Growth not restricted (3·5-4 cm. in 14 days); red exudate drops absent	*P. Adametzi*

Penicillium lapidosum Raper and Fennell. Mycologia, 40, 1948.

Malt. The colony diameter measures 7 cm. in 14 days. The surface is covered with sclerotes. Penicilli are formed sparingly, and do not contribute to the general colour of the culture. At an early stage the central part is russet-vinaceous (XXXIX), outwards buff-yellow (IV)* with a white powdery margin. Pale pink

*All colour references are to Ridgway, 1912.

exudate drops may be present. As the colony ages, the surface appears to be powdered with ochraceous buff tints (XV), due to maturing of the sclerotes.

The reverse early shows shades of salmon colour, later deepening at the centre to russet-vinaceous with a paler margin.

Czapek. The colony diameter at 14 days is 3·5-4 cm. The central surface is corinthian to etruscan red (XXVII), studded with pink exudate droplets. Beyond the centre, it is maize to buff-yellow (IV). The whole area is powdery with sclerote formation, and the margin rather fimbriate and uneven.

The reverse is not buckled, pale-flesh to flesh colour (XIV), darkening at the centre to deep vinaceous (XXVII), and the margin of the colony is usually cream in colour.

Raulin. The colony diameter in 14 days is comparable to that on malt. The surface, for the most part, is brownish to russet-vinaceous (XXXIX) and glistening with small pink exudate drops. Outwards, the surface colour is maize yellow (IV), with a white margin.

The reverse is buckled, salmon-buff (XIV), with a creamish to white margin.

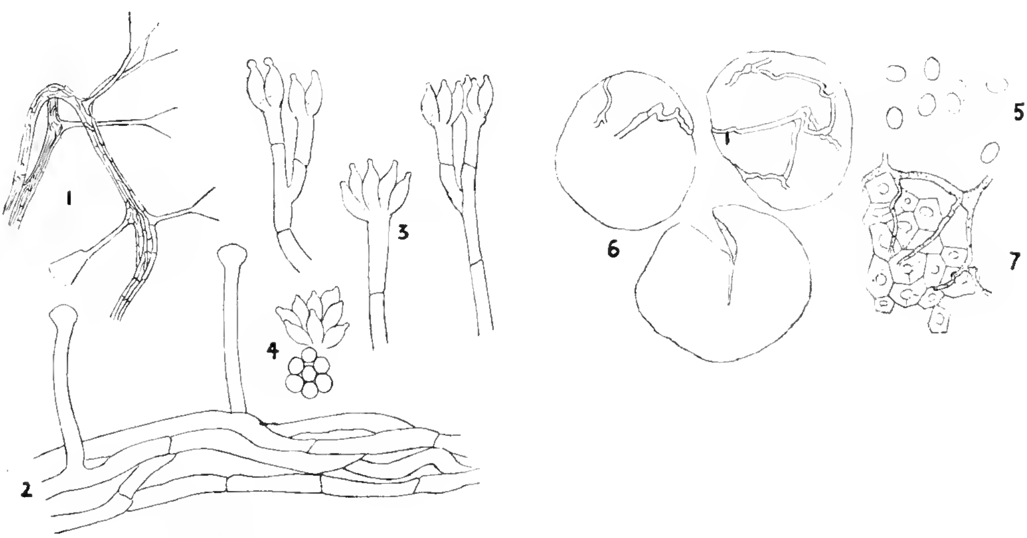

FIG. 1.—*P. lapidosum* Raper and Fennell. 1. Habit, × 50. 2. Rope, × 460. 3. Details of penicillus, × 460. 4. Sterigmata seen from above and laterally, × 460. 5. Spores, × 460. 6. Sclerote, × 50. 7. Detail of sclerotial tissue, × 460.

Morphology. The very sparsely formed conidiophores arise from trailing hyphae or from ropes of hyphae. They are frequently septated and smooth-walled, sometimes very short (10 μ), often 20-25 μ in length and sometimes longer. Many of them bear penicilli of the monoverticillate pattern. Others are characterized by the presence of an adpressed branch, about 10 μ long, close to their apices. The sterigmata are 5-7 μ long × 2-2·5 μ broad, and are borne in tight clusters over the slightly enlarged conidiophore tips. They bear somewhat tangled chains of spores. The conidia are elliptical, 2·5-3 × 2 μ; occasionally some appear sub-globose and are smooth-walled.

The sclerotes are variable in size, reaching 250-300 μ. They are yellow-brown when viewed under low magnification, but they are encrusted by thick-walled

orange-brown hyphae, and similar hyphae often form a network between them. The sclerotes are hard and difficult to crush; they consist of thick-walled cells, with an average diameter of 7-10 μ, with walls about 2-3 μ broad. On crushing, their contents escape in the form of immense numbers of oil droplets.

The features of diagnostic significance are:

(1) The predominantly monoverticillate character of the penicilli.

(2) The production of sclerotes on all three media.

(3) The yellow-brown colour of the sclerotes with the investing deep-coloured hyphae.

Isolated from the litter lying under *Leptospermum myrsinoides* and *Banksia marginata* on the sandy podsol at Frankston, Victoria, when plated out with malt agar at 40°, 60° and 80° C.

Penicillium Thomii Maire. Bul. Soc. Hist. Nat. Afrique. Nord., 8, 1917.

Malt. The colony diameter measures 6·5 cm. in 14 days. The surface is velvety, artemisia green (XLVII), with a suggestion of zoning outwards, and a narrow white margin.

Malt slopes, of the same age, but incubated at 25° C., show small orange-pink (II) sclerotial patches. Similarly coloured sclerotes are also present on malt plates incubated at room temperature, but they are not easily seen with the eye, as they seem to be buried in the substratum. (When this form is first isolated, sclerote formation is plentiful on this medium, but rapidly decreases on sub-culturing.)

The reverse shows pale green sporing shades through the agar, with salmon colours developing (XIV), fading outwards to the margin.

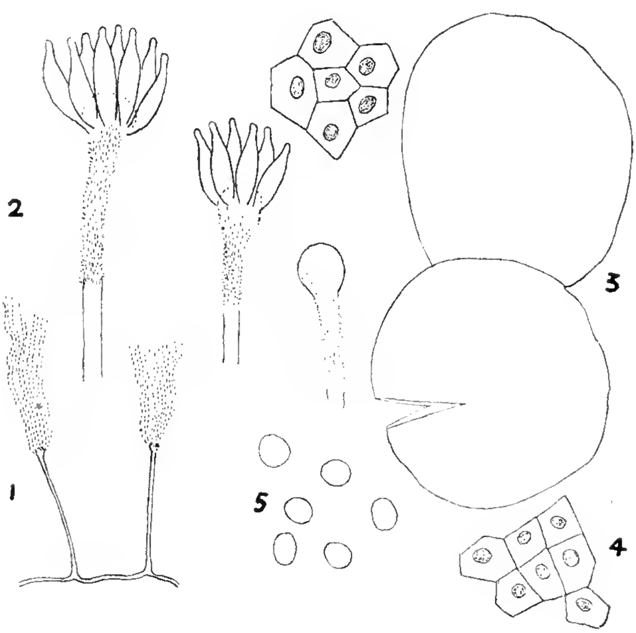

Fig. 2.—*P. Thomii* Maire. 1. Diagram of habit. 2. Details of penicillus, × 600. 3. Sclerote, × 35. 4. Sclerotial cells, × 600.

Czapek. The colony diameter measures 3 cm. in 14 days. The surface is smooth, becoming uneven or lightly floccose at the centre; at first artemisia to lily green, becoming deep slate-olive (XLVII), with a broad white margin; no visible sclerotes.

The reverse is slightly buckled at the centre, salmon colour (XIV).

Raulin. The colony diameter at 14 days measures 6 cm. The surface is velvety, lily-green to slate-olive (XLVII), zoned outwards with a white margin. Pinkish sclerotes are present at the centre of the colony, and small colourless exudate drops are present.

The reverse is similar to that on Czapek, but the buckling is more pronounced.

Morphology. The monoverticillate conidiophores arise from the basal felt or from trailing hyphae. The walls are rough, and the ends are inflated to form conspicuous vesicles 5 μ broad, on which are borne numerous rather parallel sterigmata 8-10 μ long; the sterigmata tend to be deciduous. The spore chains form rather loose columns; the spores are elliptical to sub-globose, smooth-walled, 3-3·5 μ in their long axis. The mature sclerotes are english red to mars orange (II); they are approximately 250-350 μ in diameter, their walls having the appearance of sclerenchyma-like tissue, which makes them hard and brittle.

The features of diagnostic significance are:

(1) The formation of pink sclerotia on all three media, especially when the strain has been recently isolated.

(2) The hard and brittle nature of the sclerotia.

(3) The monoverticillate penicilli.

(4) The elliptic to sub-globose, smooth spores.

Isolated from litter under *Leptospermum myrsinoides, Leucopogon virgatus* and *Casuarina distyla,* when plated out with malt agar at 60° and 80° C.

Penicillium pusillum Smith. Brit. Mycol. Soc. Trans., 22, 1939.

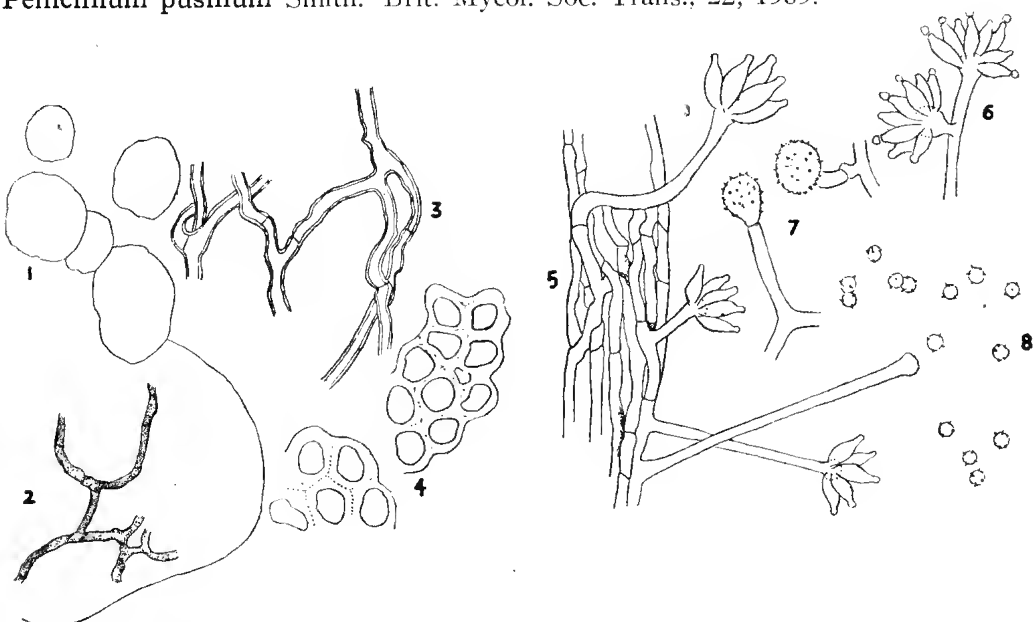

FIG. 3.—*P. pusillum* Smith. 1. Sclerote, × 50. 2. Sclerote, × 220. 3. Hyphae on surface of sclerote, × 460. 4. Sclerotial tissue, × 460. 5. Details of rope and conidiophore, × 460. 6. A branched conidiophore, × 460. 7. Vesicles of old conidiophores from which the sterigmata have fallen, × 460. 8. Spores, × 460.

Malt. The colony diameter measures, at 14 days, 4·5-5 cm. The surface is slightly mealy, lily-green, passing into a bluish-green colour towards the edge of the sporing area, and with a broad white margin which later becomes deep slate-green (XLVII). Small yellow sclerotes are present, but not visible from above, as they are embedded in the felt. Malt slopes of the same age show a white felted

mycelial overgrowth. In this area, exudate droplets form and, as they dry out, give a pitted appearance to the surface, and in this mat the sclerotes form.

The reverse is greenish-buff, the buff colour being more marked at the centre, and the margin is cream.

Czapek. In 14 days the diameter of the colony measures 2·5-3 cm. The growth on this medium remains very thin, and sporing is much reduced, in lily-green shades forming a network over the surface. The margin is fimbriate. Sclerotes are not present.

The reverse is uncoloured, with patches of green, which correspond to the sporing areas on the upper surface.

Raulin. The colony diameter measures 4 cm. at 14 days. The surface is velvety, pale glaucous blue (XLII), with small colourless or pale yellow exudate drops and a narrow white margin.

The reverse is buckled and coloured avellaneous (XL) to cream.

Morphology. The smooth-walled conidiophores arise either from trailing hyphae or from well-defined ropes. Some of them are very short (8-10 μ), but the greater number are 50 μ or longer. Most of them are strictly monoverticillate, but occasionally a branch occurs close to the vesicular apex. Numerous sterigmata arise over this surface and bear spores in tangled chains. The tinted spores are globose, 2 μ in diameter, with rather sparsely developed, small but distinct echinulations on their walls.

The sclerotes are soft and readily crushed, averaging 100 μ. They are yellow, with orange-brown hyphae adhering to their surface, and composed of cells about 5 μ in diameter, with walls 1-1·5 μ thick.

These isolations differ from the description of the type species in the pale reverse (lack of purple pigment) and the rough nature of the spore wall. The other characters agree well, and the spore shape and size are in accord. For these reasons the Australian forms have been placed in Smith's species, though they represent probably a variant of his type.

The features of diagnostic significance are:

(1) No formation of sclerotes on Czapek agar.

(2) The soft character of the sclerote wall.

(3) The globose, small spores.

Isolated from litter under *Banksia marginata* and *Leptospermum myrsinoides,* when samples were plated out with both malt and Czapek agar at 40° and 80° C.

Penicillium spinulosum Thom. U.S. Dept. Agr. Bur. Anim. Ind. Bull., 118, 1910.

Malt. The diameter of the colony measures 5-16 cm. in 14 days. The surface is velvety to sparsely floccose; at first, artemisia green (XLVII), but later darkening towards deep slate-olive with a tendency to zonation; white margin.

The reverse shows a cream background at first, with some green colour showing through in a faintly zoned pattern. Later, light ochraceous salmon tints (XV) appear at the centre of the colony, and this pinkish colour spreads outwards.

Czapek. The colony diameter at 14 days is 3·5-4 cm. The surface is velvety or sparsely floccose, with the same colours as on malt agar. Colurless exudate drops are often present over the sporing area.

The reverse is buckled, and cream with pinkish or buff tints sometimes showing.

Raulin. The colony diameter at 14 days is approx. 4 cm. The surface is similar to that on Czapek and malt agars.

The reverse is buckled; at first cream, but developing pinkish shades close to buff pink (XXVIII).

Morphology. The conidiophores arise most commonly from the substratum; some, however, arise from trailing hyphae, so they are of variable length. They may be smooth or rough walled, and are often septated; each enlarges at its apex to form a vesicle approximately 5 μ wide, which bears a whorl of sterigmata over its surface. They average from 7 to 10 μ in length, and narrow towards the spore-bearing end. The spores are borne in long, narrow, rather frayed columns (300 μ), and they appear to increase in size quickly, as there is not much gradation in size between the six or eight that remain on the sterigmata in fluid mounts. The connectives are distinct. The spores are globose to sub-globose, 3-3·5μ in diameter, roughened with short spines.

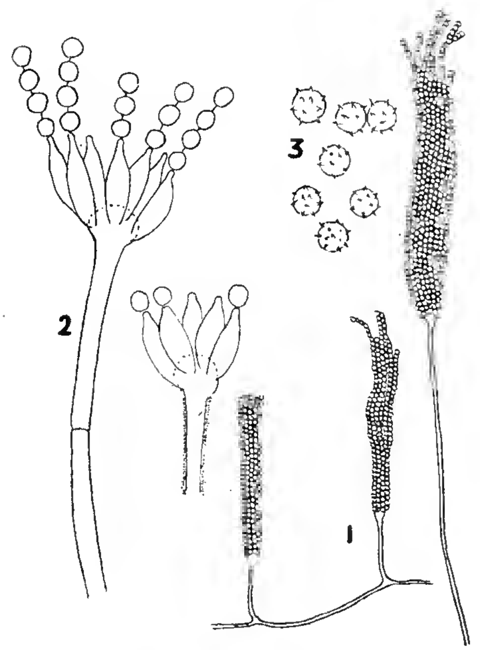

FIG. 4.—*P. spinulosum* Thom. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

The diagnostic features of significance are:

(1) The velvety surface.

(2) The pale reverse on all three media.

(3) The globose, spiny spores.

Isolated from the A and B horizons of the Frankston sandy podsol; it is one of the commonest forms in the A horizon. It was also obtained from the Mallee soils at a depth of 18 in.

Penicillium purpurrescens (Sopp) Raper and Thom. Raper and Thom, A Manual of the Penicillia, 1949.

Malt. The colony diameter is 5-5·5 cm. in 14 days. The surface is velvety; in early growth the sporing colour is greyish blue-green (XLVIII), becoming slate-olive to deep slate-olive (XLVII), or dull greenish black, faintly zonate, with a white margin; colourless exudate drops may be present.

The reverse is pale, with the dark sporing shades eventually showing through. A pale purple colour may develop at the centre of the growth.

Czapek. The colony diameter measures 2·5 cm. in 14 days. The surface is velvety and radiately furrowed. The sporing colours are much as for malt, sporing practically to the edge of the colony; pale amber exudate droplets may form.

The reverse is slightly buckled. At first pale, but later developing some vinaceous brown colour (XXXIX).

Raulin. The colony diameter is 3 cm. in 14 days. The surface is velvety, and

radially furrowed. The sporing colour is much as for malt, but denser, zonate, with a white margin and colourless exudate droplets.

The reverse is pale at first, buckled, tawny to russet brown (XV) colours developing at the centre, and extending outwards.

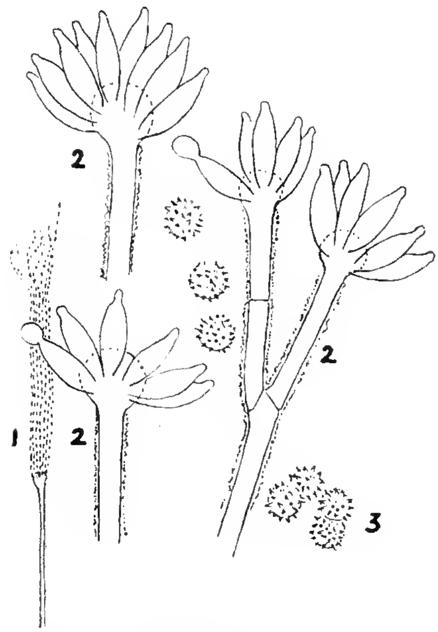

FIG. 5.—*P. purpurrescens* (Sopp) Raper and Thom. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

Morphology. The rough-walled conidiophores arise close to the substratum, and they enlarge markedly at their apices to form vesicles from 4 to 7 μ broad. They bear crowded sterigmata which support conidia in columns, 150-200 μ long. The penicilli are typically monoverticillate, but occasionally a branched conidiophore may be observed. The conidia are globose, 3·5-4 μ, dark coloured and conspicuously roughened, with short but porminent spines.

There is a strong, almost fetid, odour developed in culture.

The features of diagnostic significance are:

(1) The dark-coloured sporing surface.

(2) The purplish to brown colours in reverse.

(3) The large, dark coloured, spiny, globose spores.

(4) The pronounced odour.

Isolated from the A horizon of the sandy podsol at Frankston, Victoria.

Penicillium frequentans Westling. Archiv für Botanik, 11, 1911.

Malt. The colony diameter measures 6 cm. in 14 days. The surface is velvety, in age becoming slightly furrowed, artemisia green (XLVIII) or bluish grey-green (XLII); the colour is very uniform right across the colony surface; outwards it may be faintly zoned, with a narrow white margin.

The reverse has a background of yellowish citrine (XVI), with orange (III) or ochraceous orange (XV) in the centre and spokes of similar colour radiating out from it; in some strains, little of the orange colour appears.

Czapek. The colony diameter measures 4 cm. in 14 days. The surface is velvety, bluish grey-green (XLII), with some overgrowth of paler hyphae and a white, rather strigose, margin.

The reverse is slightly buckled, mars yellow (III), in some strains closer to ochraceous orange (XV); paler towards the margin, the yellow colour diffuses into the medium.

Raulin. The diameter of the colony measures 6 cm. in 14 days. The surface is velvety, with similar colours to those on Czapek agar.

The reverse is slightly buckled radially, and is cinnamon to Prout's brown

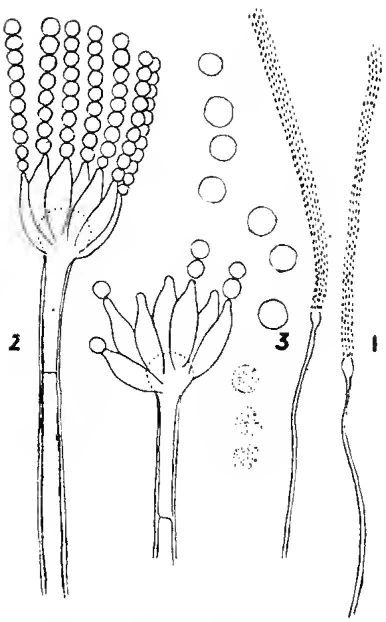

FIG. 6.—*P. frequentans* Westling. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

(XV); the colour is fairly uniform, with a pale margin.

Morphology. The long conidiophores arise from the basal felt and enlarge at their ends into vesicles 5 μ broad. They are smooth-walled, occasionally they may be slightly roughened, and bear crowded clusters of sterigmata 8-10 μ long. These support long chains of conidia grouped together to form long narrow columns about 350 μ × 10 μ. The spores are globose, 2·5 to 3 μ in diameter, with walls smooth or sometimes finely roughened

The features of diagnostic significance are:

(1) The velvety surface.

(2) The deep yellow to brown colour of the reverse.

(3) The globose, smooth, or at most finely roughened, spores.

Isolated from the B and C horizons of the Frankston sandy podsol, and from the litter of *Ricinocarpus pinifolius*, as well as from the B horizon (15 in.) of a mountain loam at Bogong High Plains, Victoria.

Penicillium restrictum Gilman and Abbott. Iowa State College Journ. Sci., 1, 1927.

Malt. The colony diameter at 14 days measures 2·5 to 3 cm. (in some isolations reaching 4 cm.). The surface is slightly floccose and is essentially pearl grey to hathi grey or deeper (LII), but this colour may be masked by the intense development of blood-red exudate drops giving a reddish colour to the greater part of the colony; in other strains, bright yellow drops are mixed with the red, and give a multi-coloured surface; while in others only yellow or colourless drops appear. The margin is pale and abrupt.

The reverse varies with the strain. Those forms with bright coloured drops are characterized by colours close to primuline yellow to old gold (XVI), with the deeper colour sometimes in zones. When the drops are paler, the reverse is lemon chrome (IV). All isolations show a yellow colour in the surrounding agar.

Czapek. The colony diameter at 14 days measures 2 cm. The surface is floccose and varies from hathi grey (LII) to nearly white. Bright yellow exudate characterizes most strains; when first isolated many of them develop blood-red droplets, but this character disappears after repeated sub-culturing.

The reverse is slightly buckled. At first it is uncoloured, then lemon yellow colours appear in some strains; this deepens in age to citron yellow (XVI), and the yellow pigment diffuses into the medium.

Raulin. The colony diameter at 14 days measures 2 to 2·5 cm. The surface is floccose and may develop pale grey shades, more often remaining white, with yellow and colourless exudate drops.

The reverse is buckled. The colony tends to lift away from the agar in a dome-shaped fashion. The colour is lemon yellow.

Morphology. Numerous trailing hyphae cover the surface of the colony, and from these arise very short conidiophores; the average length lies between 10 and 25 μ. These are smooth-walled, and bear over their slightly inflated tips a number of short sterigmata, averaging 5 μ long. The penicilli are small structures, and do not support long spore-chains. The spores are globose, 2 μ in diameter, clear and echinulate when young, becoming brownish in age, and the surface markings become blunter and somewhat tuberculate in character.

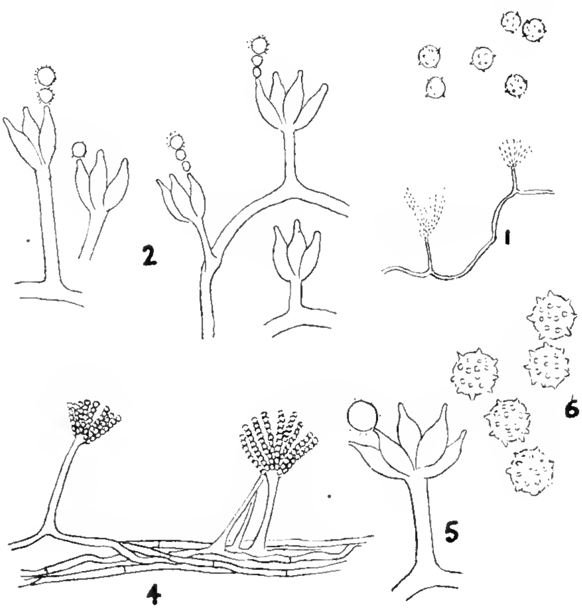

Fig. 7.

P. restrictum Gilman and Abbott. 1. Habit sketch. 2. Details of conidiophore and penicillus, × 600. 3. Spores, × 600.

P. fuscum (Sopp) Raper and Thom. 4. Habit sketch. 5. Details of conidiophore and penicillus, × 600. 6. Spores, × 600.

The forms included here all agree in possessing small, globose and spiny spores, similar to those formed by the culture labelled N.R.R.L. 1748 (see Raper), but the cultural characters vary with the different isolations, and particularly from those shown by the American form, which in our experience never shows the bright red and yellow exudate drops nor the bright yellow reverse on any of the three media. In age, however, N.R.R.L. 1748 on malt becomes light pinkish cinnamon (XXIX), and on Czapek straw yellow (XVI).

The features of diagnostic significance are:

(1) The restricted growth on all three media.

(2) The floccose surface in tones of pale grey, often masked by brightly coloured droplets.

(3) The yellowing of the media beyond the colony edge.

(4) The small, globose, spiny and brown-coloured spores.

Isolated from the A, B and C horizons of the Frankston sandy podsol, and from the B horizon (9-14 in.) of a mountain loam at Bogong High Plains, Victoria. Also from the rhizosphere of roots of *Epacris impressa* and *Hibbertia sericea* growing on the Frankston heathland.

Penicillium fuscum (Sopp) Raper and Thom. Raper and Thom, A Manual of the Penicillia, 1949.

Malt. The colony diameter measures 3 cm. in 14 days. The surface is floccose, pearl grey (LII), sometimes with pale yellow exudate drops; margin abrupt.

The reverse is cream, and in age brown tones may develop

Czapek. The colony diameter measures 2·5-3 cm. in 14 days. The surface is floccose, remaining white for some time, but eventually tints of pearl to hathi grey develop (LII), and numerous colourless exudate droplets appear in the central region.

The reverse is slightly buckled, and cream coloured.

Raulin. The colony measures 2 cm. in 14 days. The surface is floccose, with characters as described for Czapek.

The reverse is irregularly buckled, and cream, but later becomes clay-coloured.

Morphology. The smooth-walled, or slightly roughened, conidiophores arise from trailing hyphae or from well-defined ropes of hyphae. Many are short, about 10 μ, but some may reach 40 μ or more. They are monoverticillate in type, with slightly inflated ends, and bear a crown of short sterigmata. These are 5-8 μ long, and are constricted towards their tips. The conidia are arranged in tangled masses, and when mature they are dark-brown, globose, large, 4-4·5 μ in diameter, and ornamented with blunt spines. The young spores, while still attached to the sterigmata, are colourless and spinulose. Many of the spores appear to fail to reach maturity.

In the early stages of growth the cultural characters of our isolations appear very similar to those of N.R.R.L. 1748 (*P. restrictum*), but in the later stages they differ in the absence of the yellow tints in reverse, and the yellow exudate droplets. It is the spore characters that suggest they approximate to *Penicillium fuscum* as interpreted by Raper *et al.*, but they differ from this species as described by them in the restricted growth on malt agar.

The features of diagnostic significance are:

(1) The restricted growth on all media.
(2) The monoverticillate penicilli.
(3) The *large*, coloured, rough-walled, globose spores.

Isolated from a mountain loam at Bogong High Plains, Victoria, from the B horizon at 9-14 in. level.

Aspergillus Sydowi (Bain and Sart) Thom and Church. Thom and Church, The Aspergilli, 1926.

Malt. The colony diameter measures 6-7 cm. in 14 days. The surface is slightly floccose, and zoned, dark olive-grey to deep olive-grey to olive-grey (LI), with a narrow white margin.

The reverse is cream, with dark green sporing shades showing through in a zoned pattern.

Czapek. The colony measures 2·5-3 cm. in 14 days. The surface is slightly floccose. At the centre the colour is slate-olive, but the greater part of the surface is in shades of blue-green near to gnaphalium green (XLVII), with light amber exudate drops.

The reverse is buckled. In some strains it is at first cream, in others clay-coloured (XXIX), and deepens to cameo brown (XXVIII), with a tendency towards redder hues; the pigment diffuses into the surrounding medium. The paler strains show patches of similar colour in age.

Raulin. The growth rate is similar to that on malt. The surface is floccose; dark olive-grey to paler shades (LI), with a white margin. Sometimes numerous pale exudate drops may be present.

The reverse is buckled, cream at first, later brownish areas develop.

Morphology. The conidiophores arise either from trailing hyphae or sometimes from well-developed ropes. They are usually rough-walled and very variable in length, 15 μ to 150 μ (many about 50 μ). Each is inflated into a distinct vesicular head, 5-6 μ broad. The sterigmata arise over its surface, and tend to be parallel to one another; sometimes they are rough-walled, and they are constricted below the point of origin of the spores. The spore chains form distinct narrow columns, at least on malt agar. The conidia are globose, brown, 3-3·5 or even 4 μ, and

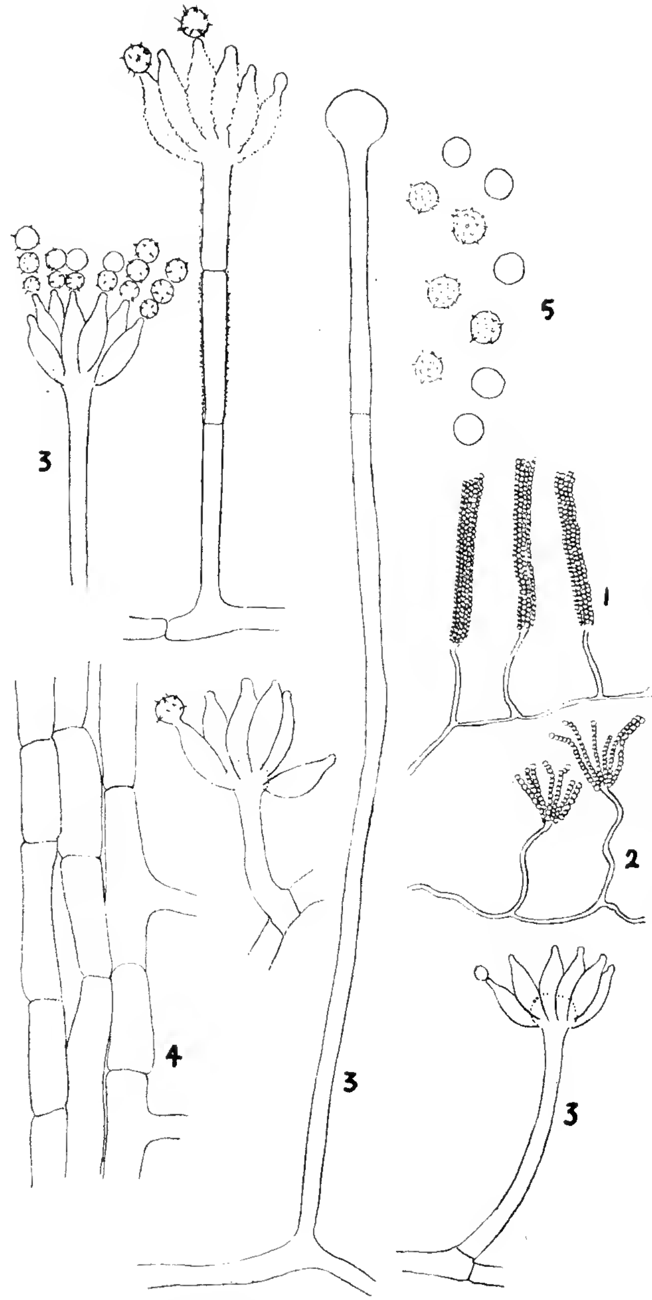

FIG. 8.—*Aspergillus Sydowi* (Bain. and Sart.) Thom and Church. 1. Habit sketch from malt agar. 2. Habit sketch from Czapek agar. 3. Details of conidiophore and penicillus, × 600. 4. Details of rope, × 600. 5. Spores, × 600.

roughened by blunt spines which are almost tuberculate in form.

These isolations show the restricted growth on Czapek agar, and the brown, rough, globose spores that characterize *Penicillium restrictum,* but the growth on malt and Raulin agars differs markedly from the growth of that species. Raper examined one of our isolations (PVA_8) and suggested that it represented *P. restrictum* Gilman and Abbott, but said 'it is rather unique in producing penicilli which are unusually large for this species.' We have had these isolates in culture for some time and they consistently show the characters as described and figured here. The relationship between *P. restrictum* and *Aspergillus Sydowi* has been discussed by Raper and Thom, and we have, with some hesitation, interpreted our form as representing a strain of *Aspergillus Sydowi.*

The features of diagnostic significance are:

(1) The restricted growth on Czapek agar, but spreading colonies on malt and Raulin's agar.

(2) The production of reddish-brown pigment in reverse on Czapek, with diffusion of the pigment into the medium.

(3) The brown, globose and roughened spores.

Isolated from a mountain loam at Bogong High Plains, Victoria, from the A and B horizons (0-32 in.).

Penicillium fellutanum Biourge. La Cellule, 33, 1923.

Malt. The colony diameter measures 1·5-2 cm. in 14 days. The surface is floccose, and remains white for some time, but finally becomes flecked with pea green (XLVII).

The reverse is yellow, close to citron yellow (XVI), but becomes paler in age. When the plates are incubated at 25° C., the yellow colour is more intense and it may diffuse into the surrounding agar.

Czapek. The colony diameter measures 1·5-2 cm. in 14 days. The surface is floccose. At first, it is white, but later pea green colours develop, and sometimes pale yellow exudate drops occur.

The reverse is buckled, and cream buff (XXX) in colour.

Raulin. The rate of growth is similar to that on Czapek. The surface is floccose and white, with pea green colours developing later.

The reverse is buckled, and lifts away from the medium in a dome-like manner; cream buff (XXX).

Morphology. The conidiophores are not numerous. They arise mostly from trailing hyphae, and are comparatively short, 20-30 μ in length, and smooth-walled. Each bears a few sterigmata, 5-6 μ long, over the inflated ends. The spores are borne in short columns; they are sub-globose, smooth-walled, and are 2·5-3 μ in diameter.

The features of diagnostic significance are:

(1) The floccose, rather than velvety, surface of the colony.

(2) The sparsely sporulating surface in shades of pea green.

(3) The pale-coloured reverse.

Isolated from the B horizon of the Frankston sandy podsol.

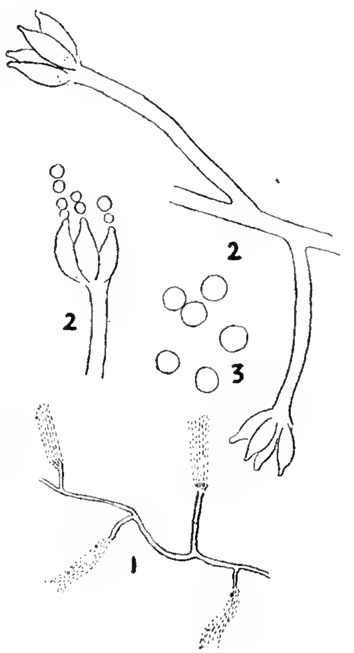

FIG. 9.—*P. fellutanum* Biourge. 1. Habit sketch. 2. Details of condiophores and penicillus, × 600. 3. Spores, × 600.

Penicillium lividum Westling. Archiv. für Botanik, 11, 1911.

Malt. The colony diameter measures 6 cm. in 14 days. The surface is very lanose, greyish blue-green to deep greyish blue-green (XLVIII), with a narrow white rim.

The reverse is plane, ochraceous salmon to ochraceous orange (XV), with slight zoning towards the paler margin.

Czapek. The diameter of the colony at 14 days is approximately 4 cm. The surface is lanose, deep greyish blue-green, outwards deep glaucous grey (XLVIII), with a narrow white rim and compact margin. The outer part of the surface is faintly zoned.

The reverse is plane, and light ochraceous salmon (XV).

Raulin. The colony diameter is 5-5·5 cm. in 14 days. The surface is lanose, deep greyish blue-green at the centre and paler beyond, with slight pitting from drying out of the colourless exudate drops.

The reverse is slightly puckered, cinnamon, passing into verona brown (XXIX), and some pure yellow colours close to the margin

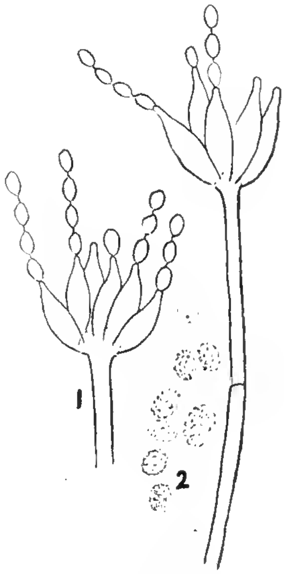

FIG. 10.—*P. lividum* Westling. 1. Details of penicillus, × 600. 2. Spores, × 600.

Morphology. The long conidiophores arise from the basal felt, and have slightly roughened walls. They are septated, and swell out into a depressed globose vesicle which bears parallel sterigmata 10 μ in length over its surface. Each narrows perceptibly close to the conidial producing tip. The conidia are produced in tangled chains. Each spore is elliptical, with conspicuous connectives between them, while still attached in the penicillus. When mature, they are variable in size, generally elliptic, averaging $3 \times 2{\cdot}5\ \mu$, occasionally $5 \times 3\ \mu$. They are rough-walled and greenish in colour.

The features of diagnostic significance are:

(1) The greyish blue-green colours of the sporing surface.

(2) The long conidiophores arising from the basal felt.

(3) The elliptical, roughened spores.

Isolated from the Mallee soils at the 28 in. level.

Penicillium vinaceum Gilman and Abbott. Iowa State Coll. Journ. Sci., 1, 1927.

Malt. The colony diameter at 14 days measures 2-2·5 cm. The surface is lanose and mainly white. The deep felt, however, overlies yellow hyphae. Sporulation is sparse; in age, a slight greyish colour is visible in the sporing areas. Pinkish to blood-red exudate drops are present, but not so abundantly as on other media. The margin of the colony is abrupt.

The reverse is plane, mikado to verona brown (XXIX).

Czapek. The rate of growth is similar to that on malt agar. The surface is essentially white, with some yellow mycelium present. Exudate drops form so abundantly that they give the characteristic appearance to the colony. The young drops are in light red tones, quickly passing into blood red, and in age becoming almost black or very deep blood-red.

The reverse is slightly buckled and furrowed. Early, it is terra cotta to pecan brown (XXVIII). The colour is intense to the edge of the colony, and later it deepens to maroon (I) or darker. The colour diffuses into the medium, and appears brazil red or deeper (I).

Raulin. The colony measures 2-2·5 cm. at 14 days. The surface is lanose, and white, with blood-red droplets across the surface. These do not darken as do those on Czapek.

The reverse is buckled, and is chocolate to burnt umber in colour (XXVIII).

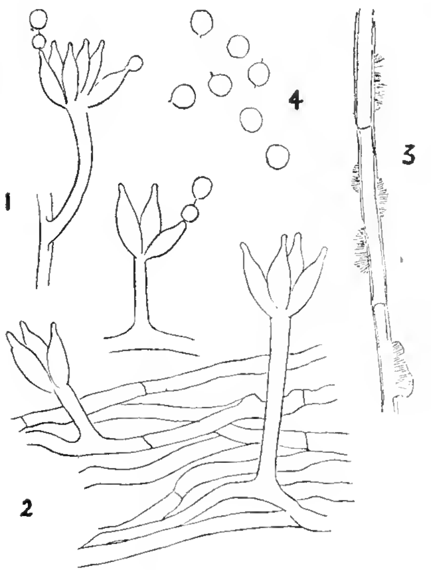

FIG. 11.—*P. vinaceum* Gilman and Abbott. 1. Conidiophore and penicillus, × 600. 2. Rope with conidiophores, × 600. 3. Hypha with incrustation, × 600. 4. Spores, × 600.

Morphology. The hyphae are encrusted with yellow or red crystalline deposits, and the short conidiophores, 10 to 20 μ, or occasionally longer, arise from trailing hyphae or sometimes from ropes of hyphae. The monoverticillate penicilli consist of a few sterigmata, 6-8 μ in length. Each narrows to a conidial tube and supports a chain of globose spores in which the connectives are conspicuous. The spores are sub-globose, mostly about 2 μ in diameter, often apiculate from the persistent connective, smooth or slightly rough-walled.

The features of diagnostic significance are:

(1) The restricted growth on all three media.

(2) The abundance of deep red exudate drops of Czapek and Raulin agars.

(3) The sparse formation of sporing heads.

(4) The short conidiophores and apiculate small spores.

Isolated from the Mallee soils (Mildura) at the 6 in. level. Ninety per cent of the isolations at this level were *P. vinaceum*.

Penicillium Adametzi Zaleski. Bul. Acad. Polonaise Sci.: Math. et Nat., Ser. B, 1927.

Malt. The colony diameter measures 4·5 cm. in 14 days. The surface is mealy, often becoming tufted in the centre, lily green to deep slate green (XLVII), zoned outwards, the margin white and partly submerged.

The reverse is isabella colour (XXX), sometimes intensifying to a deep yellow or ochraceous orange (XV) at the centre, fading towards the margin. The yellow pigment diffuses into the medium beyond the colony.

Czapek. The colony diameter measures 3-3·5 cm. in 14 days. The surface is floccose to almost velvety, in light green shades close to artemisia or lily green (XLVII), and zoned, with a white margin. Yellow exudate drops may be present.

The reverse is buckled, in yellow colours varying from wax yellow (XIV) to cadmium orange (III). Some isolations show paler colours, near to ochraceous buff and ochraceous salmon (XV). The yellow pigment may diffuse into the medium.

Raulin. The colony diameter at 14 days measures 4 cm. The surface is floccose to mealy, artemisia to lily green, with a white margin. Overgrowths of white mycelium are common. Colourless to pale yellow exudate drops may occur.

The reverse is buckled, with brownish shades developing on a yellow ochre background (XV), often in a zoned manner.

Morphology. The conidiophores may arise from trailing hyphae that form a close felt on the colony surface, or from ropes of hyphae which may sometimes become so profuse as to form coremial-like masses. The conidiophores are smooth-walled in some isolations, rough in others, and occasionally may bear a branch some distance from the apex. The ends are swollen out to form a distinct vesicle 5 μ broad; eight or more sterigmata arise over this inflated surface. They average about 8 μ in length, and they support chains of spores arranged in long narrow columns (250-300 μ). The spores are sub-globose, 2-2·5 μ in diameter, with smooth, or sometimes granulated, walls.

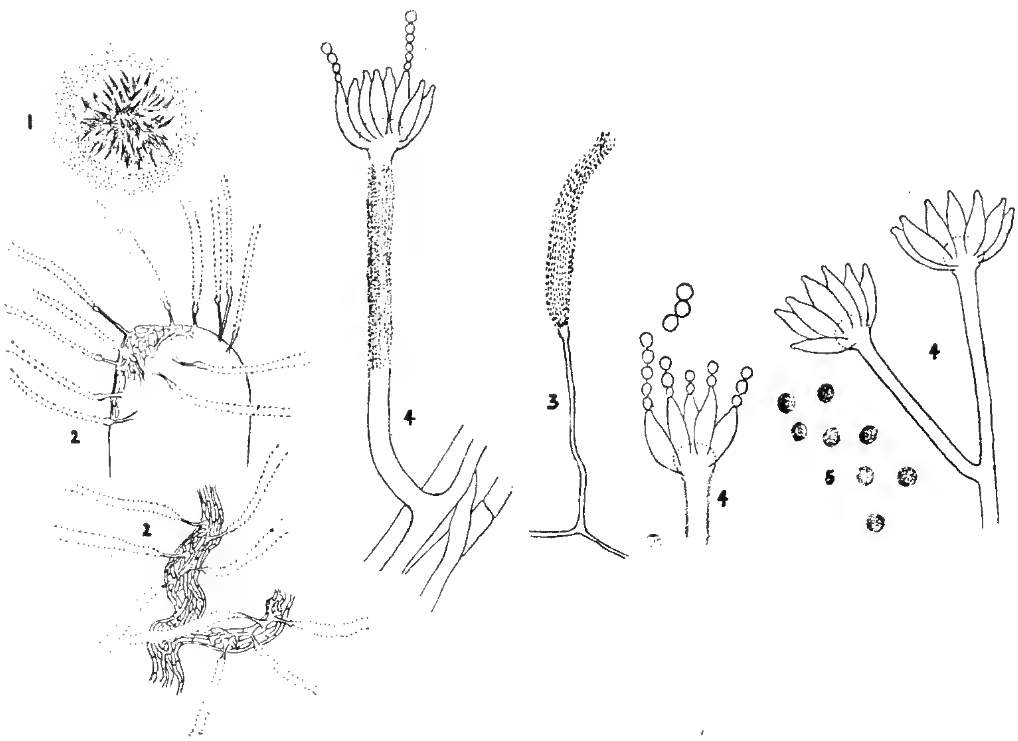

FIG. 12.—*P. Adametzi* Zaleski. 1. Surface of colony (diagram). 2. Sketch illustrating ropy habit. 3. Sketch of single conidiophore. 4. Details of conidiophore and penicillus, $\times$ 420. 5. Spores, $\times$ 420.

The features of diagnostic significance are:

(1) The predominantly funiculose habit.

(2) The yellow to orange or brown colours in reverse on Czapek and Raulin's agar.

(3) The smooth, sub-globose spores.

Isolated from the A, B and C horizons of the Frankston sandy podsol, and from samples of the litter present under the plants growing on it, when plated out with malt or Czapek agar at 60° and 80° C. Also isolated from the Mallee soils at 6 in. and 12 in. levels.

THE MONOVERTICILLATA-RAMIGENA

The *Monoverticillata-Ramigena* series includes those members of the genus that have the characteristic monoverticillate penicilli with conspicuously vesicular heads but the conidiophores are branched. Sometimes there is only one branch and the placement of such forms into the series is not difficult; sometimes there are several branches arising more or less at the same level and these forms approximate to the *Lanata-divaricata* pattern.

KEY TO THE MONOVERTICILLATA-RAMIGENA

1.	Spores globose, rough	*P. Waksmani*
	Spores elliptic, smooth	*P. cyaneum*
	or	
1.	Sporing colour on Czapek, slate olive	*P. Waksmani*
	Sporing colour on Czapek, pale gnaphalium-green to storm-grey ..	*P. cyaneum*

Penicillium Waksmani Zaleski. Bul. Acad. Polonaise Sci.: Math. et Nat., Ser. B, 1927.

Malt. The colony diameter in 14 days is from 3 to 4·5 cm. The upper surface is mealy, and becomes deep slate olive (XLVII); towards the margin a greyish blue-green (XLVIII) is seen with a very narrow and abrupt white edge. The whole surface is faintly zoned.

The background of the reverse is at first cream, but later zones of brown shades occur regularly to the margin. The amount of zoning and the intensity of the colour varies with the strain and temperature of incubation.

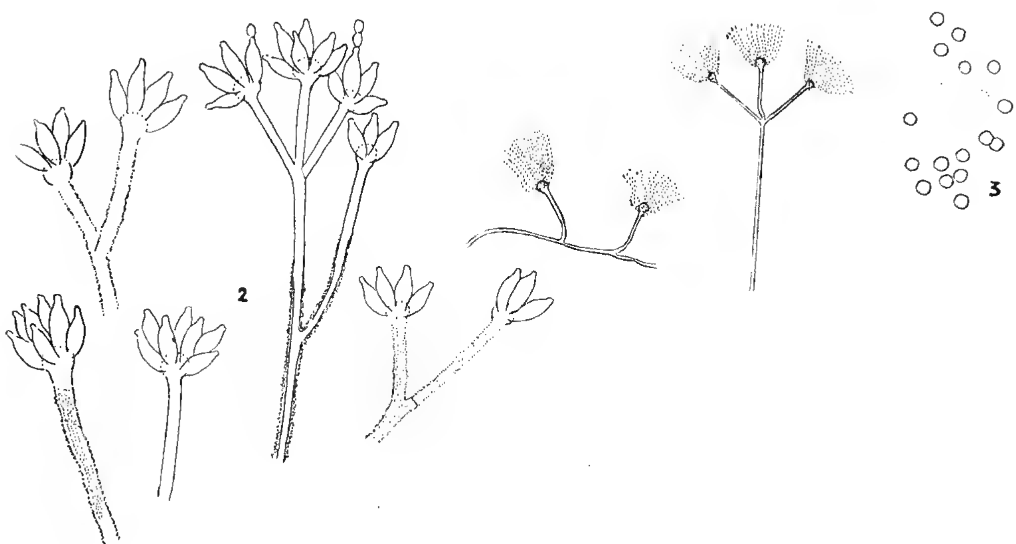

FIG. 13.—*P. Waksmani* Zaleski. 1. Habit sketch. 2. Details of conidiophore and penicillus, × 420. 3. Spores, × 420.

Czapek. In 14 days the colony diameter is 2-2·5 cm. The characteristic feature is the very thin growth on this medium, a feature constant for all the strains that have been isolated. The amount of sporing is reduced and occurs mainly towards

the centre, where the colour is deep slate olive. There is a broad transparent white margin to the colony.

The reverse is colourless; the colour of the sporing heads shows through.

Raulin. The diameter of the colony is 3-3·5 cm. The surface is almost velvety, slate olive or greyish blue-green (XLVIII). The centre lifts away from the medium and some overgrowth of white mycelium may occur. There is a narrow white rim to the colony.

The reverse is much buckled. It is at first cream, passing through shades of yellow, with zones or patches of brown colour. The brown colour intensifies with age and becomes darker than the reverse on malt agar.

Morphology. Conidiophores arise either from the substrate or from trailing hyphae, occasionally from well defined 'ropes'. They are rough-walled and very variable in length, some of them very short. Many of the conidiophores are of the simple monoverticillate type. Others are branched, some with a branch distant from the apex or with three branches closer to the tip and forming a rather divaricate pattern. All the branches have a pronounced vesicular head (3-4 μ) which bears a group of sterigmata 5-7 μ long. These bear the spore chains which form rather tangled masses and are not in definite columns. The spores are globose, small, mostly 2 μ in diameter, with slightly roughened walls.

The features characteristic of this form are:

(1) The restricted growth on all three media.

(2) The very poor growth on Czapek medium.

(3) The rough-walled conidiophores.

(4) The small, globose and delicately roughened spores.

The isolations represented by this description do not fit readily into any described species. Raper, after examination of one of the isolates (4 A_6), remarks in correspondence that 'he would not care to assign a specific name to this strain,' but he believes it to approximate to *P. Waksmani* Zaleski, and we agree that it doubtless represents a variety of this species.

Isolated from the A horizon of the sandy podsol at Frankston, Victoria, and from the Mallee soils, Mildura, at 70 in. level.

Penicillium cyaneum (B. and S.) Biourge. Liste Onomastique, La Cellule 33, 1923.

Malt. At 14 days the colony diameter is 6·5-7 cm. Some slower growing strains reach only 4 cm. The upper surface is velvety, sage green to slate olive (XLVII), closely zoned with a wide (1 cm.) thin margin.

The reverse is pale with green sporing shades showing through; in age the green colour intensifies; zoned.

Malt slopes kept at 3° C. in age show a very dark green reverse.

Czapek. Growth much restricted and only slightly buckled. At 14 days the colony measures 2 cm. The surface is velvety and even in age shows pale shades; gnaphalium green (XLVII) or bluish grey-green (XLII) to storm grey (LII) with pale droplets. Later, pink colours appear in patches with many pale pink exudate drops. There is a narrow white margin.

The reverse shows shades of pinkish buff with deeper tones developing in age.

Raulin. Colony diameter is 4 cm. and buckled. The upper surface is velvety to slightly floccose with sporing colour much as on Czapek agar; the centre sometimes umbonate, due to the colony lifting away from the medium narrow white margin.

The reverse is in pale buff shades (tilleul-buff to avellaneous (XL)), fading outwards to cream. The buckling is both radial and concentric in pattern.

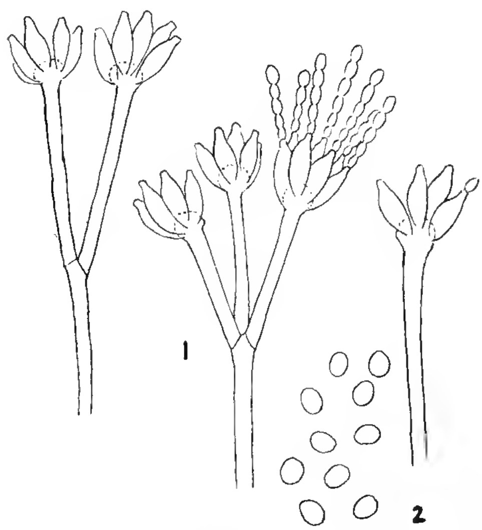

FIG. 14.—*P. cyaneum* (Bain. and Sart.) Biourge. 1. Details of penicillus, × 600. 2. Spores, × 600.

Morphology. The conidiophores arise from trailing hyphae. Some are monoverticillate, but typically they fork towards their ends. Each branch develops equally and becomes inflated at its apex. Occasionally three or more branches develop in a verticil. The sterigmata are from 5 to 7 μ long and they bear chains of spores in somewhat tangled loose columns. The spores are elliptic, 2 × 3 μ, smooth-walled in age, pale olive-tinted.

The features that characterize these 'ramigena' isolations are:

(1) The light bluish green sporing colours on Czapek and Raulin agar.

(2) The elliptic smooth-walled spores.

Isolated from the A horizon of the sandy podsol at Frankston, Victoria, and from the litter present on this soil, as well as from the rhizosphere of roots of *Epacris impressa* growing in this habitat; also from the B horizon of mountain loam at depth of 10-18 in.

THE ASYMMETRICA-DIVARICATA

Included in this section are those Penicillium species with asymmetrically branched conidiophores. The angle of branching is always wide, so the fertile system is divaricate in appearance. In some members of the group the branching, although wide, is more or less at one level (metulae) and the penicilli are then more compact but definitely spreading in form.

KEY TO THE ASYMMETRICA-DIVARICATA

1. Sclerotes present	*P. Rolfsii*
1. Sclerotes absent	2.
2. Sporing surface pinkish-vinaceous	*P. lilacinum*
2. Sporing surface not so coloured	3.
3. Ropes of hyphae present	4.
3. Ropes of hyphae absent	5.
4. Rate of growth restricted; deep brown colours in reverse, particularly on malt and Raulin agars	*P. Godlewskii*
4. Rate of growth not restricted; reverse on malt agar olive yellow with bands of olive green through it	*P. janthinellum*
4. Rate of growth not restricted; reverse on malt pale-coloured ..	*P. piscarium*

5. Conidiophore and metulae walls very rough	6.
5. Conidiophore and metulae walls smooth	8.
6. Sporing surface on Czapek and Raulin agars in shades of glaucous blue to bluish grey-green	*P. canescens*
6. Sporing surface on Czapek and Raulin agars olive grey or neutral grey to slate olive	7.
7. Spores globose and distinctly echinulate	*P. Melinii*
7. Spores globose, smooth, or only slightly roughened	*P. Raciborskii*
8. Growth on malt agar not restricted, 6-7 cm. in 14 days	*P. janthinellum*
8. Growth on malt agar more restricted, 2-4 cm. in 14 days	9.
9. Spores globose, rough, 5 μ in diameter	*P. albidum*
9. Spores globose, smaller	10.
10. Spores globose, spiny, 3 μ in diameter	*P. nigricans*
10. Spores globose, almost smooth, 3 μ in diameter	*P. Kapuscinskii*

Penicillium Rolfsii Thom. The Penicillia, 1930.

Malt. In 14 days the colony diameter is 6 cm.; the upper surface is covered with small sclerotes. The penicilli are formed sparingly and they do not contribute

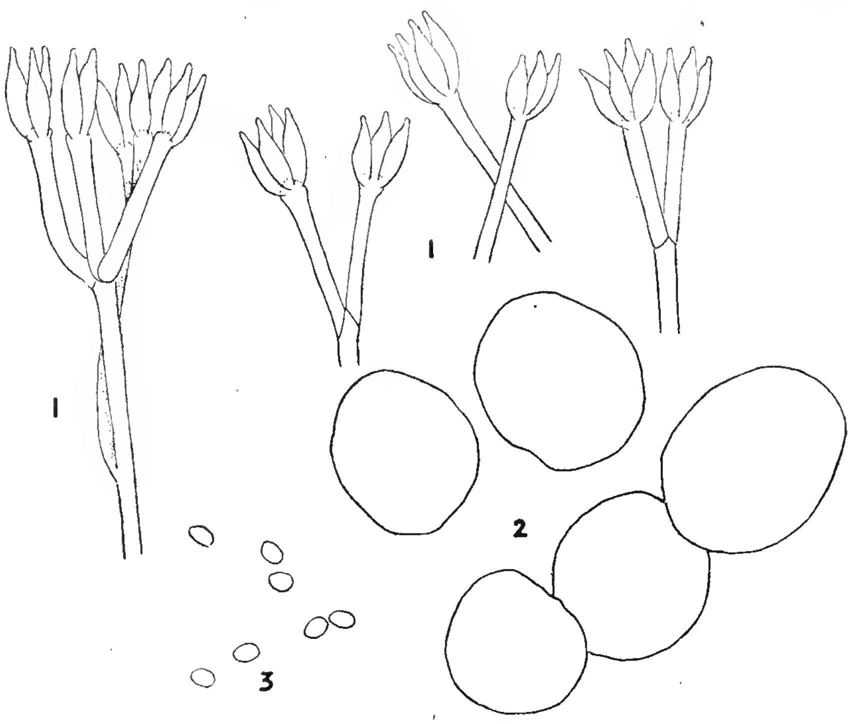

FIG. 15.—*P. Rolfsii* Thom. 1. Details of penicillus, × 600. 2. Sclerotes, × 65. 3. Spores, × 600.

to the general colour of the cultures, which is dark vinaceous to corinthian red (XXVII) with reddish exudate drops. The margin is broad, maize yellow (IV) and powdered with white sclerotes.

The reverse is salmon buff (XIV) at the centre, fading outwards to white.

Czapek. The colony is more restricted in growth on this medium. It averages in 14 days 1·5-2 cm. and is buckled. The surface shows the colour of the penicilli, lily green (XLVII) at the centre with yellow shades beyond and with a narrow white margin. At this age, sclerotes are not noticeably present on this medium, but later they form in abundance and the surface becomes deep vinaceous to light corinthian red (XXVII).

The reverse is buckled, pale flesh to flesh colour (XIV), with a white margin.

Raulin. In 14 days the colony diameter is 2-3 cm., the surface is much buckled, white, with no visible sclerotes. Later these form in abundance and the surface shows similar colours to those developed on malt agar, with numerous pale exudate droplets.

The reverse is buckled, cinnamon-clay to tawny olive (XXIX), with a white margin.

Morphology. The smooth-walled conidiophores arise from trailing hyphae. Some are of the monoverticillate type, but the majority on malt become once branched in a divaricate fashion. Each branch is 10-15 μ long, slightly swollen at the tip, and bears a few sterigmata (7-8 μ) which narrow at their tips and produce chains of smooth elliptical spores $2{\cdot}5 \times 2\ \mu$. On Czapek agar the conidiophores are more complex, often branched at some distance below the apex, and each branch bearing three or four metulae with sterigmata of similar dimensions to those on malt. The sclerotes are small, rather regular in shape, globose to elliptical, with an average size of $200 \times 160\ \mu$. Under the microscope they appear an orange-pink colour. The surface is smooth and shows an outer coat of thickened angular cells. They are hard and brittle and when cracked exude a quantity of oil, but there is never any trace of ascal development.

The features of diagnostic significance are:

(1) The formation at an early stage of growth on malt agar of the pinkish sclerotes, and their non-appearance at the same age on Czapek agar.

(2) The smooth-walled conidiophores of a divaricate pattern.

(3) The elliptic smooth-walled spores.

Isolated from the litter collected under *Banksia marginata* and *Leptospermum myrsinoides* when samples were plated out with malt agar at 60° and 80° C.

Penicillium lilacinum Thom. U.S. Dept. Agr. Bur. Anim. Ind. Bul., 118, 1910.

Malt. In 14 days the colony diameter is 5·5 cm. The upper surface is floccose, pinkish vinaceous (XXVII), with white margin.

The reverse shows shades of russet, vinaceous to sorghum brown (XXXIX) in faint zones. In age, dark shades to almost black form in the centre of the colony.

Czapek. A colony of 4 cm. diameter develops in 14 days. The surface is floccose, at first white, later becomes deeper than corinthian pink (XXVII).

The reverse is rather drab with vinaceous colours forming towards the margin of the colony.

Raulin. Rate of spread similar to that on Czapek. The surface is floccose, corinthian pink to pinkish vinaceous, the centre often overgrown with a white felt.

The reverse shows slight circular buckling and the colours that develop are similar to those on malt.

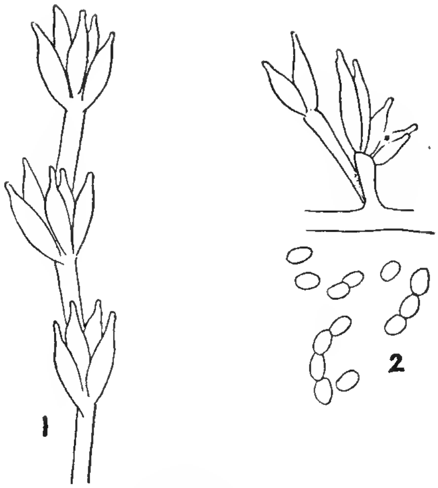

FIG. 16.—*P. lilacinum* Thom. 1. Details of penicillus, × 600. 2. Spores, × 600.

Morphology. The smooth-walled conidiophores are extremely variable in form. Sometimes they are very short, almost sessile, on aerial trailing hyphae. The longer ones arise from the substratum and bear complex penicilli of varying pattern. Sometimes verticils of sterigmata are borne for some distance along their length. The sterigmata appear to fall away readily; they are 5-8 μ long and bear rather short and tangled spore chains which fall apart on mounting. The spores are elliptical, 2·5-3 μ in their longest axis, smooth-walled and pale lilac tinted.

This species is characterized by the lilac-coloured sporing surface.

Isolated from the Mallee soils (Mildura) at 35 in. level.

Penicillium janthinellum Biourge, in Monogr., La Cellule 33, 1923.

Malt. In 14 days colony diameter is 6-7 cm., the surface is floccose. Some strains remain white for a longer period than others, but eventually become light grey (dawn to hathi grey (II)) and then greyish blue-green (XLVIII). Pink exudate drops may be present.

The reverse is olive yellow (XXX), deeper at the centre and fading outwards to paler tones. Later, characteristic bands of olive green radiate from the centre to the edge of colony.

Malt slopes in age may be vinaceous fawn (XL) or carmine to ox-blood red (I) in reverse, and the upper surface may show pink colouration mixed with the grey to drab surface.

Czapek. In 14 days the colony diameter is 4-5 cm. and the surface is slightly floccose. The isolations are variable in colour, in early growth white, and some may remain almost sterile. More usually the mycelium becomes flecked with flesh tints, and finally storm grey (LII) shades appear.

The reverse early in growth is chamois (XXX) and the later colours are very variable, from almost colourless, sometimes with pink or vinaceous shades, to rufous red (XIV) with coral red (XIII) patches.

Raulin. In 14 days colony diameter 4-5 cm., slightly floccose; hathi to storm grey (LII). Yellow exudate drops may be present; in age, deep to dark olive grey (LI).

The reverse is variable in colour in early growth but eventually shows shades of rather bright green (XXX-XXXI), with brown to red to purple (XXV) colours developed unevenly through it.

Morphology. The conidiophores arise from the trailing hyphae or sometimes from ropes. They are very variable in length, some very short (5 μ). These are of the monoverticillate type, but the majority are much longer. These may be branched at some distance from the apex. Often the conidiophore forks close to the tip and the diverging branches bear diverging metulae with swollen ends, or again the

diverging metulae (approx. 10 μ long) may be formed in a verticil. The walls of the conidiophore and of the hyphae may be roughened. The sterigmata are narrow and taper to a fine point (5-7 μ long). The spores are elliptical when formed and smooth-walled, but become sub-globose (2-2·5-3 μ) and slightly roughened when mature.

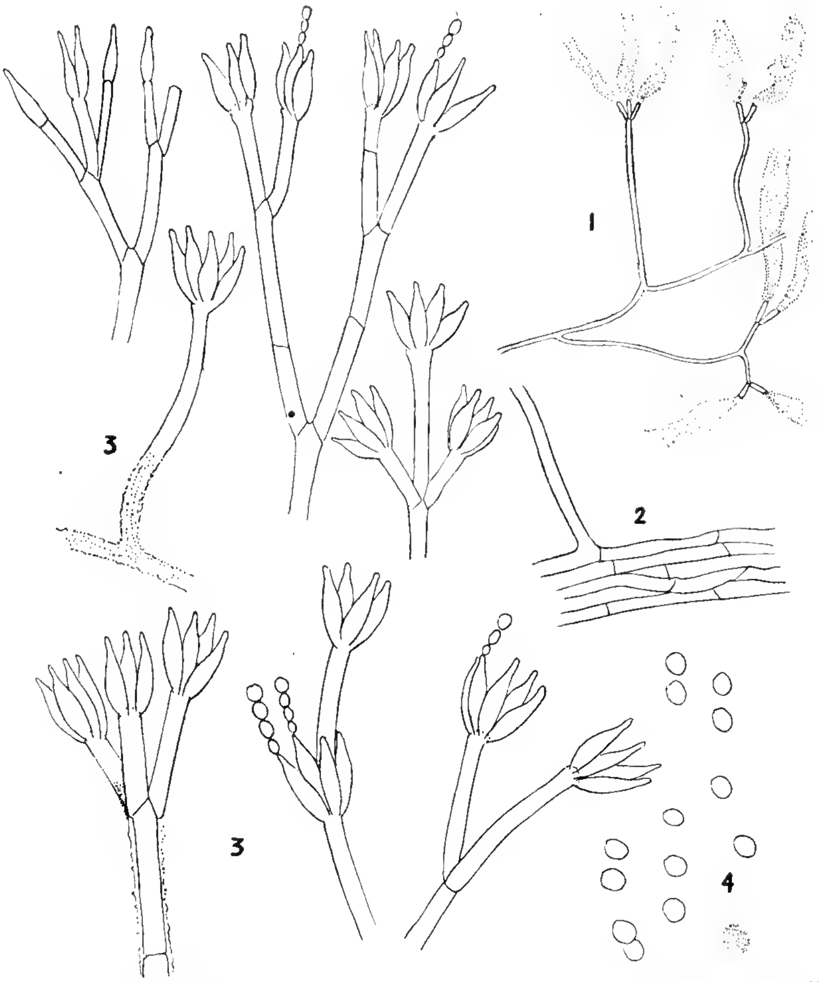

FIG. 17.—*P. janthinellum* Biourge. 1. Habit sketch. 2. Rope, × 600. 3. Details of conidiophore and penicillus, × 600. 4. Spores, × 600.

Some strains (C_{15}, A_{22}) isolated by us appeared as a rule to be predominantly monoverticillate; only occasional branched penicilli occurred. The growth characters (although occasional strains lacked the typical pigmentation), the morphology of the sterigmata, the spores and spore chains agreed with *P. janthinellum* Biourge, and Raper (in correspondence) agrees that these forms should be assigned here.

The features which are of greatest diagnostic value in this variable species are:

(1) The broadly spreading colony on malt agar, with light grey sporing shades.
(2) The character of the reverse on malt agar.

(3) The development of the pink to red shades in reverse on old malt slopes.
(4) The colours developed in reverse on Raulin's agar.
(5) The morphology of sterigmata and spores.

Isolated from the A, B and C horizons of the Frankston sandy podsol.

Penicillium piscarium, Westling in Arkiv. für Botanik II, 54, 1911.

Malt. In 14 days the colony diameter is 7-8 cm. At first the sporing surface is artemisia green (XLVII) and floccose, with slight zoning, but becomes olive grey to deep olive grey (LI).

The reverse is avellaneous to fawn (XL).

Czapek. The growth is more restricted on this medium; colony diameter at 14 days is approximately 4 cm. The colour of the sporing surface is comparable to that on malt.

The reverse is furrowed in both a circular and radial direction and is light buff (XV).

Raulin. At 14 days the diameter is 6 cm., and the surface is furrowed. The colour agrees with that on other media, but an overgrowth of white mycelium occurs in the central region.

The reverse is buckled, with patches of drab to benzo brown (XLXI) appearing.

Morphology. The conidiophores arise from trailing hyphae and are very varied in form. Sometimes they are monoverticillate or 'a divaricate group of two to several metulae' or with a mixture of branchlets and sterigmata in the verticil. The vesicular apex bears the sterigmata which vary in length from 5 to 10 μ. They are long pointed and bear long but tangled spore chains. The spores are elliptic to ovate, 2·5-3 μ in the longest axis, with echinulate thickenings.

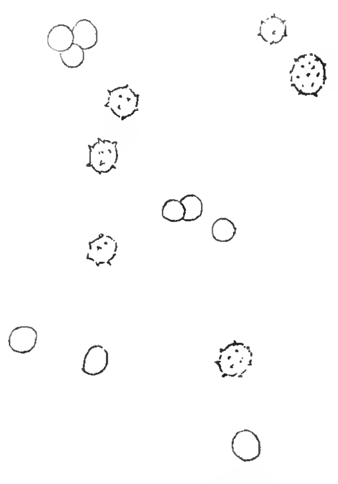

FIG. 18.—*P. piscarium* Westling. 1. Spores, × 600.

This fungus was grown also on wort agar. The type of folding or buckling of the colony as seen in reverse showed a striking cellular pattern resembling the pattern of honeycomb.

The features of diagnostic value within the *janthinellum* series are:

(1) The absence of any conspicuous colouration on any of the media used.

(2) The character of the folding on wort agar as seen in the reverse.

(3) The very variable character of the conidiophores.

(4) The echinulate elliptic to ovate spore. (The echinulations in our strain were not very well developed.)

This species has been isolated only once and was obtained from B horizon of the Frankston sandy podsol.

Penicillium canescens Spp. Monogr., 1912.

Malt. In 14 days the colony diameter is 7·5 cm. The surface is floccose; at the centre the colour is deep slate green to deep slate olive (XLVII), becoming paler

outwards, with tufts of greyish mycelium right across the surface, and with a broad white margin.

The reverse shows greenish buff shades with a faint pinkish drab centre (capucine buff or pinker (III)), and the same colour appears towards the margin.

Czapek. The colony diameter is 4·5 cm. at 14 days. The surface is floccose (not deeply) in shades of glaucous blue to bluish grey-green (XLII), the surrounding agar with vinaceous shades.

The reverse is not buckled and is russet (XV) at the centre, paler beyond in buff shades, sometimes deepening again to dull indian purple (XLIV).

Raulin. The colony diameter is 6 cm. in 14 days. The surface is floccose, deep to dark glaucous grey-green (XLII), with a few small colourless exudate drops and a white margin.

The reverse is slightly buckled at the centre. The colour is yellow ochre (XV) with some buckthorn brown shades (XV).

Morphology. The conspicuously rough conidiophores arise mainly from trailing hyphae but on malt agar some ropes are definintely present and subtend short conidiophores (40 μ long). Many of the conidiophores are comparatively simple and bear two divaricate metulae; others are more complex, and bear as many as five or six. They are 10-15 μ long and together with the conidiophore have much-roughened walls. Each metula bears a whorl of four to eight sterigmata, about 7 μ long, with a short narrow tip. The spores are borne in chains. On malt agar these chains are grouped in columns, but on Czapek agar this tendency is less pronounced. The spores are globose with rough walls 2-2·5 μ in diameter.

The features of diagnostic significance are:

(1) The very rough walls of the conidiophores and metulae.

(2) The formation of spore columns at least in young cultures.

(3) The grey-green sporing surface.

(4) The globose rough-walled spores.

Isolated from litter under *Banksia marginata,* when samples were poured with malt agar at 60° and 80° C.

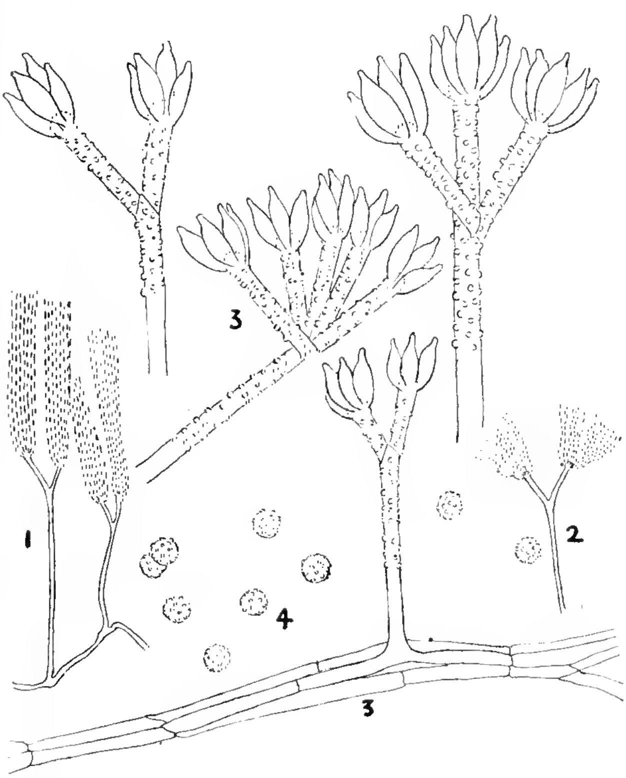

FIG. 19.—*P. canescens* Sopp. 1. Habit sketch from malt agar. 2. Habit sketch from Czapek agar. 3. Rope, conidiophores and penicilli, × 600. 4. Spores, × 600.

Penicillium Godlewskii Zaleski. Bul. Acad. Polonaise Sci.: Math. et Nat., Ser. B, 1927.

Malt. The growth on malt is somewhat restricted. In 14 days the colony diameter is 3-3·5 cm. At first the surface is almost velvety and artemisia green (XLVII), but later becomes more floccose and storm grey or deeper (LII) in colour. An exudate in the form of yellow droplets is often present in the earlier stages of growth.

The reverse is benzo brown to fuscous (XLVI). The colour appears early and diffuses out into the medium.

Czapek. In 14 days the colony diameter is 2·5-3 cm. The margin is irregular and the surface is at first white, but ultimately becomes pale green (celandine to artemisia green (XLVII); an exudate of pale yellow droplets often present.

The reverse in youth is a light greenish yellow (chalcedony yellow (XVII)), but later develops brown colours and may deepen to the dark brown characteristic of growth on malt; colouration of the medium may occur.

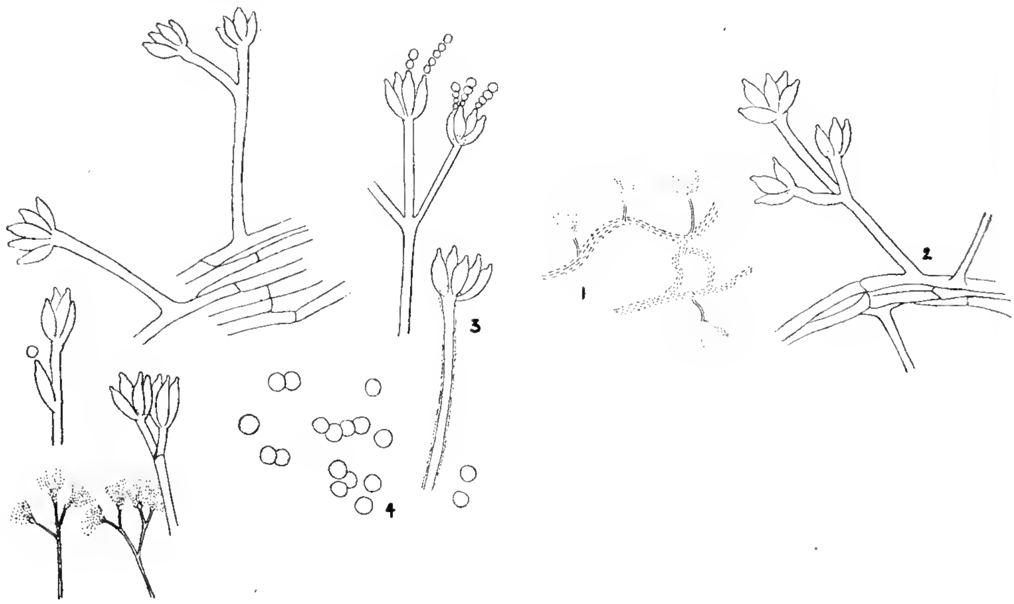

FIG. 20.—*P. Godlewskii* Zaleski. 1. Habit sketch. 2. Ropes and conidiophores, × 410. 3. Details of penicillus, × 410. 4. Spores, × 410.

Raulin. In 14 days the colony is folded with a diameter of 2·5 cm. The surface is slightly floccose. At first it is white, but later grey shades appear (mineral grey to storm grey (LII)) with an exudate of numerous yellow droplets.

The reverse is much folded and becomes intensely coloured (fuscous brown to fuscous black (XLVI)). The medium surrounding the colony may become yellowed.

Morphology. Some conidiophores (500 μ) arise singly from trailing hyphae: others from ropes, in which case they are comparatively short (15-30 μ). The walls may be smooth or slightly roughened. They bear very diversified penicilli; some are monoverticillate, with only a few sterigmata, others bear one diverging

branch, and others again are more complex but typically divaricate. The sterigmata are usually few and measure 6-8 μ long by 2-3 μ wide. They bear short tangled chains of spores which are globose to sub-globose, smooth-walled, and measure 2-2·5-3 μ.

The features of diagnostic significance within the *janthinellum* series are.

(1) The more or less restricted growth on all media (including malt).

(2) The deep brown colouration in reverse, particularly on malt and Raulin agar, with some colouration of the medium.

(3) The presence of 'ropes' from which conidiophores may arise.

(4) The shorter and blunter sterigmata.

Isolated from the A and B horizons of the Frankston sandy podsol and from the rhizosphere of *Epacris impressa* growing in that habitat.

Penicillium albidum Sopp. Monogr., 1912.

Malt. In 14 days colony diameter is 2 cm. The surface is almost velvety, at first in green tints, but becoming castor grey (LII) or deeper at the centre, fading outwards to a lighter grey colour, with a narrow white margin.

The reverse presents a faint greenish drab appearance.

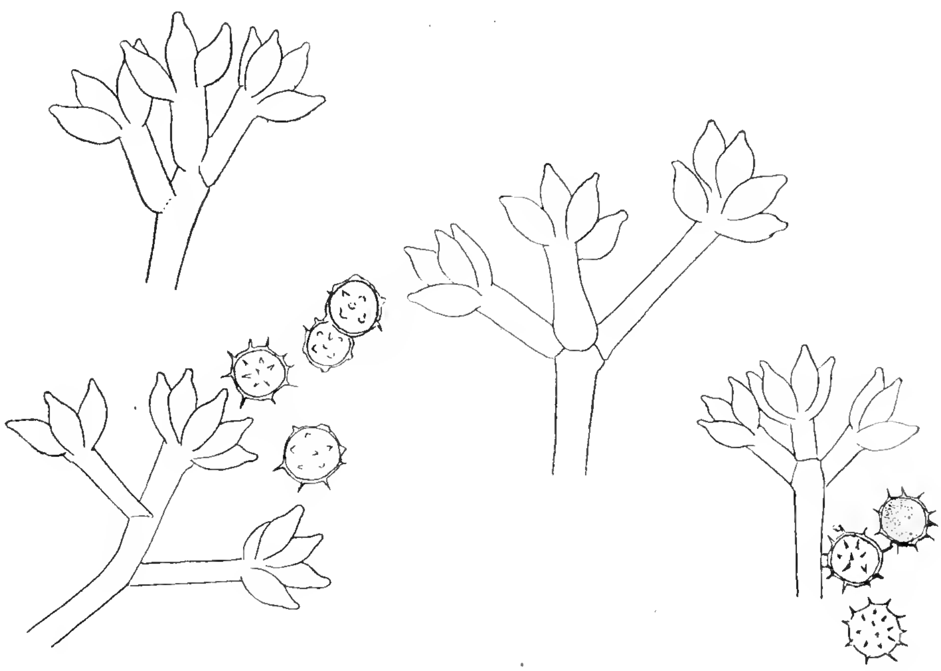

FIG. 21. *P. albidum* Sopp. 1. Details of conidiophore and penicillus, × 600. 2. Spores, × 600.

Czapek. The colony diameter is the same as that on malt. The surface is slightly floccose and entirely white.

The reverse is uncoloured.

Raulin. The growth on this medium is even more restricted and buckled, reaching only 1 cm. in 14 days. The sporing surface is slightly floccose and in light grey tones.

The reverse tends to lift away from the agar and shows slight yellowish-green tones.

Morphology. The smooth-walled conidiophores arise from trailing hyphae or from the substratum. They often appear to be truly bi-verticillate and symmetrical, but even then the metulae are slightly diverging; at other times the divergence is more marked, usually 8-10 or 12 μ; occasionally an odd one may be 20 μ. Each bears a whorl of six or eight short and plump sterigmata; 5 μ is the average length. The spores readily fall away; they are globose, light brown, 5 μ in diameter, and distinctly and rather coarsely echinulate. In old spores the thickenings appear blunter at the tips.

A number of the penicilli conform to the Bi-verticillate symmetrical pattern, but it does not agree with any of the known species in that section and as there are always some divaricate fruiting structures, it is probably best considered in the *Asymmetrica-divaricata.*

The identification of this form is provisional. It remains white and floccose on Czapek and forms echinulate globose spores comparable to those of *P. nigricans.*

The reverse does not show reddish yellow shades as recorded by Sopp for *P. albidum* and the spores are larger than 4 μ, the size quoted by Raper and Thom for a strain received from the Centraalbureau under this name.

The distinctive features are:

(1) The restricted growth on all the media used.
(2) The penicilli which approach the symmetrical pattern.
(3) The large globose echinulate spores.

Isolated from the Mallee soil (Mildura) at 12 in. level.

Penicillium Kapuscinskii Zaleski. Bul. Acad. Polonaise Sci.: Math. et Nat., Ser. B, 1927.

Malt. The colony diameter at 14 days is 2·5 cm. The surface is floccose, with a sporing colour from storm grey to hathi grey (LII) with a very narrow white margin.

The reverse is close to antimony yellow (XV). Malt slopes are closer to olive grey (LI), with pale yellow mycelial overgrowths; the reverse similar to the plates.

Czapek. The rate of growth is the same as on malt; the surface very pale, mostly white, with yellow exudate drops; hathi grey colour develops towards the margin.

The reverse is slightly buckled, cream with reddish colours developing beyond the centre.

Raulin. The rate of growth as above; the surface mostly white with numerous deep yellow exudate drops, pale tints of hathi grey here and there over the surface.

The reverse is slightly buckled; buckthorn brown to yellow ochre (XV), paler towards the margin.

Morphology. The conidiophores are similar to those of *Penicillium nigricans.* The microscopic feature that characterizes this species is found in the spores, which resemble those of *nigricans* in size, but which have a finely roughened epispore.

The distinctive features of this species are:

(1) The close resemblance to *P. nigricans.*
(2) It differs from that species in the generally paler colours, of both the sporing surface and reverse, produced on agar media,

(3) And in the finely roughened to almost smooth spore surface.
Isolated from Mallee soils (Mildura) 8 in. from surface.

Penicillium melinii Thom. The Penicillia, 1930.

Malt. In 14 days colony diameter is approximately 3 cm. The colony is orbicular, floccose; at first mineral grey, but later becomes deep to dark olive grey (LI) with a narrow white margin. Numerous colourless exudate droplets are formed over the surface.

The reverse is somewhat zoned and shows shades of greenish buff, becoming putty coloured.

Czapek. The growth on this medium is at the same rate as on malt. The surface is floccose, at first white then deep to dark olive grey with numerous yellow exudate droplets and a narrow white margin.

The reverse is at first greenish buff, but later pink colours appear which in age may deepen to vinaceous tints; puckered.

Raulin. The rate of growth is as on the other media. The surface is floccose and at first mineral grey with yellow droplets, becoming greyish olive to deep greyish olive (XLVI), the centre appearing almost an orange colour from the large and brightly coloured drops; smaller coloured droplets form almost to the colony edge.

The reverse is greenish buff in youth but becomes dark vinaceous brown to seal brown (XXXIX) and puckered.

Morphology. The rough-walled conidiophores are borne on trailing hyphae. They are variable in length. They may be monoverticillate in type or each towards the apex may bear one or more diverging branches (metulae) which are swollen at their tips and bear a varying number of stergimata, 5-7 μ. The spore chains are short and form diverging tangled masses. The spores are globose, 2·5 μ in diameter, distinctly echinulate and pale tinted.

Distinctive features of this species of the *nigricans* series are:

(1) Grey sporing shades on all media.
(2) Pale-coloured reverse on malt and Czapek agar.
(3) The rough-walled divaricate conidiophores which bear echinulate globose spores.

Isolated from the A and C horizons of the Frankston sandy podsol.

Penicillium nigricans (Bainier) Thom. The Penicillia, 1930.

Malt. The colony diameter at 14 days is from 3·5 to 5 cm.; floccose; the sporing surface storm to castor grey (LII), margin white; in some strains white mycelial overgrowths appear at centre and spread irregularly across the colony surface. On malt slopes pale (pink) exudate droplets may occur.

In reverse shades of sayal brown to sepia (XXIX) extend practically to the margin. Sometimes the brown colour diffuses into the medium.

Czapek. Growth is more restricted on this medium. At 14 days the diameter is from 3 to 4 cm. The surface is floccose and puckered. Some isolations only tardily develop sporing colours which vary from glaucous grey (XLVIII) to storm grey (LII), with numerous pale yellow exudate droplets.

The reverse is at first pale and puckered radially, sometimes buckling upwards; buffy patches appear and in some isolations the colour deepens as on malt.

Raulin. The rate of growth is comparable to that on Czapek agar. The surface is floccose and puckered; at first storm grey but deepening to castor grey; pale yellow exudate droplets present.

The reverse is in deep brown shades at the centre (benzo brown to fuscous (XLVI)) with vinaceous buff tints beyond. The puckering is in a radial and a concentric pattern.

Morphology. The smooth conidiophores arise from trailing hyphae or from the substratum. They are very variable in length. Many of them are very short, 10-15 μ before branching; the longer ones are variously branched. Sometimes a branch arises some distance from the apex but ultimately the branches and the axis itself give rise to three or more diverging metulae approximately 10 μ long. These are swollen at their tips and bear rather short (5-7 μ) and stout sterigmata. The spore chains form short twisted masses. The spores are globose, averaging 3 μ, brown and spiny.

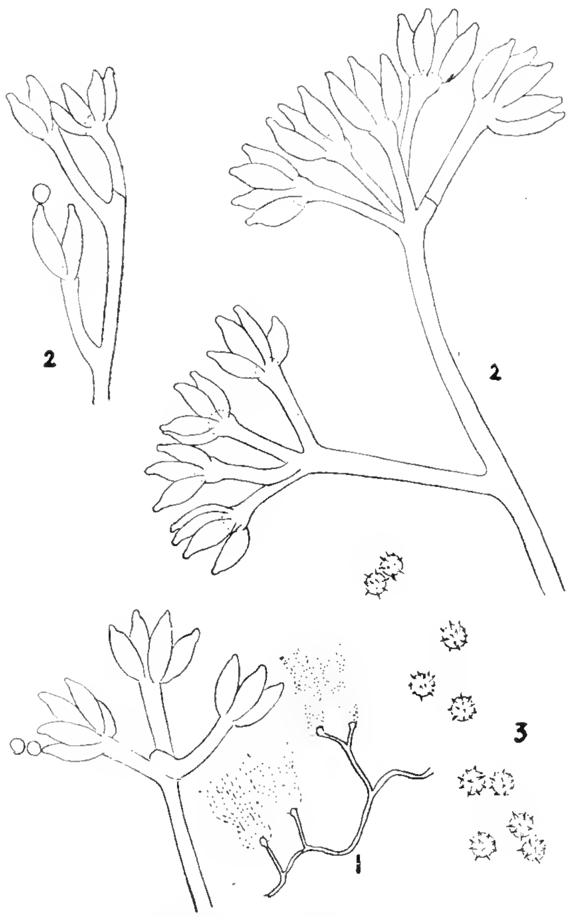

FIG. 22.—*P. nigricans* (Baimer) Thom. 1. Habit sketch. 2. Details of conidiophore and penicillus, × 600. 3. Spores, × 600.

The features of diagnostic value for this species are:

(1) The grey sporing shades on all media.

(2) The dark brown colours formed in reverse on malt and Raulin; sometimes also on Czapek.

(3) The smooth divaricate conidiophores bearing brown-coloured and spiny spores.

Isolated from the A, B and C horizons of the Frankston sandy podsol and from the litter under *Epacris impressa,* as well as from the Mallee soils (Mildura) at 5 in., 6 in. and 8 in. levels; also from a mountain loam at Bogong High Plains, Victoria, at 5-13 in. depth.

Penicillium Raciborskii Zaleski. Bul. Acad. Polonaise Sci.: Math. et Nat., Ser. B, 1927.

Malt. In 14 days the colony diameter is 4-4·5 cm. The sporing surface is at first velvety, but becoming floccose; slate olive (XLVII) at centre, paler at margin.

The reverse develops ochraceous orange shades (XV) and the colour may diffuse out into the surrounding medium.

Czapek. Growth on this medium is slower than on malt agar; 3·5 cm. in 14 days. The sporing surface at first is mineral grey to gnaphalium green (XLVII). It later becomes shades of neutral grey (LIII), with the edge almost sky-blue; abundant yellow droplets may or may not form over the folded surface.

The reverse varies with the isolation; sometimes ochraceous orange in centre, fading conspicuously towards the margin, sometimes paler in peach shades, developing in age to vinaceous tints.

Raulin. Rate of growth comparable to that on malt agar (4 cm.). In youth the upper surface is white with yellow droplets present. Later it becomes court grey or deeper (XLVII), dark yellow droplets mostly present, and the surface is puckered.

The reverse becomes ochraceous orange (XV) or deeper and is puckered, often in a circular pattern.

Morphology. The microscopic characters agree closely with those described for *P. melinii.* The conidiophores are coarsely roughened and the spores are globose, 2 μ, with a finely roughened wall.

This species is closely allied with *P. melinii,* from which it differs in spore characters. They are smaller on the average and not echinulate, although our isolations show the wall to be finely roughened.

Isolated from the B horizon ('coffee-rock') of the Frankston sandy podsol.

THE ASYMMETRICA-VELUTINA

Key to the Asymmetrica-velutina

1.	Normal type of growth occurring on Czapek agar	2.
1.	Very poor thin growth on Czapek agar and no sporing colours developed	*P. digitatum*
2.	Reverse of colonies developing yellow pigments on the three media ..	*P. chrysogenum*
2.	No yellow pigments formed; the reverse in vinaceous to purplish shades	*P. meleagrinum*

Penicillium digitatum Sacc. Mycotheca italica Padua, 1898-1913.

Malt. The colony diameter measures 7-7·5 cm. at 14 days; although spreading, the growth is thin and velvety. The sporing colour is in yellow-green shades, best matched as mignonette (XXXI) to vetiver green (XLVII); there is an irregular white margin.

The reverse shows the green shades through the thin mycelial mat.

Czapek. The growth is exceedingly thin, but stretches across 3 cm. in 14 days. No sporing colours develop.

Raulin. The growth is also very thin, but measures 4-6 cm. at 14 days. Mignonette shades develop late (12 days).

The reverse is pale; the sporing colour shows through and in age pale vinaceous fawn shades develop.

Morphology. On malt agar the conidiophores vary in length. They bear sporing heads that are difficult to observe in microscope mounts. Towards the apex the branches arise irregularly, but the pattern of the penicilli is of the asymmetric type. Each branch may bear either metulae or sterigmata or both. The sterigmata are

of variable length; in our isolations they were approximately 20 μ long, and they support long and lax spore chains. The spores vary in shape and size, even in the same spore chain. They are usually elliptic to long cylindrical, 7 × 4 μ to 10 × 4 μ, smooth and dark green in mass.

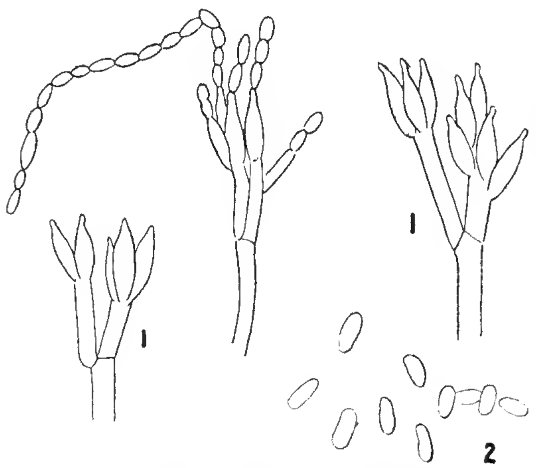

FIG. 23.—*P. digitatum* Sacc. 1. Details of penicillus, × 290. 2. Spores, × 290.

This species is characterized in the velvety series of the *Asymmetrica* by:

(1) The poor growth on Czapek agar.

(2) The colour of the sporing surface on malt.

(3) The strong odour developed in culture.

(4) The morphology of the penicilli and spores.

Isolated from the A horizon of the Frankston sandy podsol, and from Mallee sand (Mildura) at a depth of 8 in.

Penicillium chrysogenum Thom. U.S. Dept. Agr. Bur. Anim. Ind. Bul., 118, 1910.

Malt. The colony diameter measures 6 cm. at 14 days. The upper surface is velvety; at first artemisia to lily green, in age it becomes deep slate green (XLVII), passing outwards to lily green with a white margin. Pale to deep yellow droplets form over the area. In some strains isolated from soil the droplets are colourless.

The reverse is typically strontian yellow to yellowish citrine (XVI). The yellow pigment diffuses out into the medium. Occasionally strains are isolated that show a pale reverse and no colouration of the medium occurs.

Czapek. The colony diameter at 14 days measures 3-4 cm. The upper surface is velvety; at first gnaphalium green, later deep bluish grey-green (XLII) to lily green; and densely covered with yellow droplets; with a white margin. In age the surface may be floccose and faint shades of pink may develop in the hyphae.

The reverse is buckled radially. Early it is an intense light greenish yellow, becoming chalcedony yellow (XVII). Some strains develop a vinaceous tint at first, but later yellow colours appear (more quickly at warmer temperatures), and the yellow pigment diffuses into the medium.

Raulin. The diameter of the colony at 14 days is 3·5-4·5 cm. The sporing surface, which is velvety to slightly floccose, passes from artemisia green through lily green to deep bluish grey-green with numerous yellow to pale droplets and a narrow white margin.

The reverse is circularly buckled; at first chamois (XXX), in some strains the colour quickly changes to empire or apricot yellow (IV) with yellow pigment in the medium. In others the reverse remains in pale shades.

Morphology. The conidiophores arise from the substratum or from trailing hyphae. They are long, smooth-walled, and bear one or more branches near their

tips. Each branch, as well as the main axis, supports a verticil of metulae; each metula is 10-12 μ long. The sterigmata (10 μ) stand close together, so that the whole head is of a typical bi-verticillate asymmetric type. The spore chains are columnar. The spores are elliptical, 3-4 μ $\times$ 2·5-3·5 μ, and smooth.

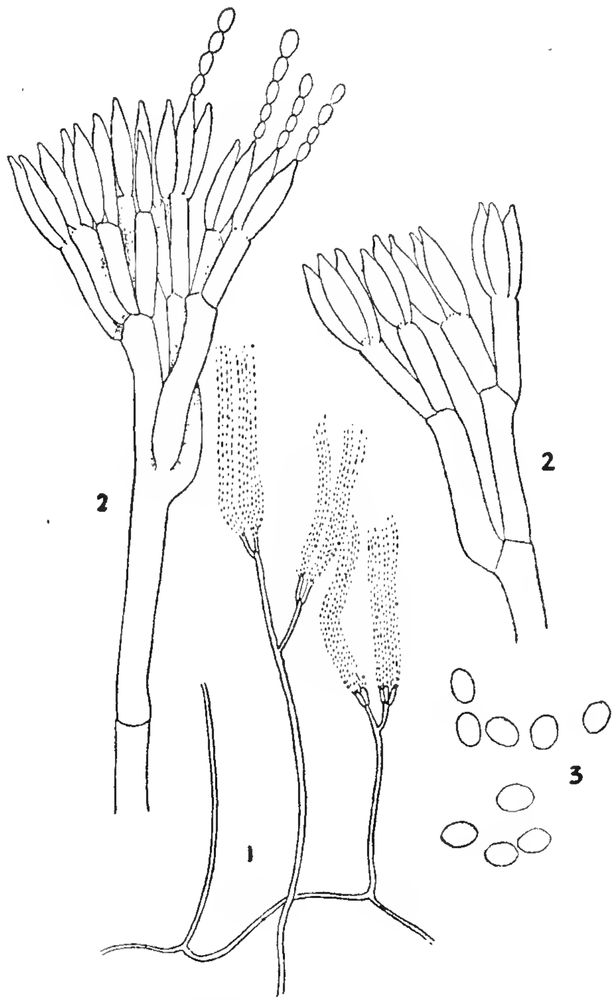

FIG. 24.—*P. chrysogenum* Thom. 1. Habit sketch. 2. Details of penicillus, $\times$ 600. 3. Spores, $\times$ 600.

The features characteristic of this species:

(1) The production of the yellow pigment in reverse and its appearance in the medium when the fungus is grown on Czapek agar. In some strains it is late in appearing and much reduced in intensity.

(2) The smooth-walled conidiophores and smooth elliptic rather large spores. Isolated from the B and C horizons of a sandy podsol at Frankston, Victoria.

Penicillium meleagrinum Biourge. La Cellule, 33, 1923.

Malt. The colony diameter in 14 days was 6-7 cm. The upper surface is velvety and becomes dark american green (XLI) to lily green (XLVII) and zoned. The degree of zonation varies with the strain. There is a white margin. Colourless or pale yellow exudate droplets occur.

The reverse shows the green sporing shades through the otherwise uncoloured background. In age, a pink to vinaceous colour develops towards the centre.

Czapek. The colony measures 4-4·5 cm. in 14 days. The upper surface is velvety and develops colours similar to those on malt and numerous colourless droplets form. There is a narrow white margin.

The reverse is slightly buckled. At first it is avellaneous (XL) and later it shows dull purplish tones.

Raulin. The diameter at 14 days is 4 cm. The velvety upper surface is artemisia to celandine green (XLVII) when young, but darkens to lily green in age. Colourless or pale yellow droplets may occur.

The reverse is very buckled and develops drabish brown tints.

Morphology. The smooth-walled conidiophores are long and arise close to the substratum. One or more branches may arise close to the apex; each bears three or more metulae. They in turn bear groups of sterigmata about 7-8 μ long. These bear long conidial chains, adhering in column-like masses. The spores are elliptical, smooth-walled, 3-3·5 μ × 2-2·5 μ in size.

This species is close to *P. chrysogenum*, from which it may be distinguished in culture by:

(1) The vinaceous to purplish colours developed in reverse on Czapek agar.

(2) The lack of any pronounced yellow pigment, the production of which characterizes most strains of *P. chrysogenum*.

Isolated from the B horizon 'coffee rock' of a sandy podsol at Frankston, Victoria, and from the rhizosphere of *Epacris impressa* growing in that habitat.

THE BREVI-COMPACTUM

Penicillium brevi-compactum Dierckx. Soc. Scien. Brux., 25, 1901.

Malt. The colony diameter measures 1·3 cm. in 14 days. The surface is radially furrowed and velvety, in youth tea to vetiver green (XLVII), passing to andover green with a narrow cream abrupt margin.

The reverse is buckled, cream-buff to chamois (XXX).

Czapek. The growth is very restricted. The diameter measures 1 cm. or less at 14 days. In some strains of MIA_8 the colonies remain very thin and produce few sporing heads; in others the surface is velvety, in some strains remaining pale, close to vetiver green, in others darkening slate-olive to deep slate-olive (XLVII). Numerous pale exudate drops may be present.

The reverse arches away from the medium; in the pale strains it is cream-buff, in the darker strains it is deep to dark olive-grey (LI).

Raulin. At 14 days the colony diameter is 1·2 cm. The surface is elevated and velvety with similar colours to those developed on Czapek agar. The colour extends to the margin, which is abrupt.

The reverse is arched away from the medium and buckled with colours similar to those on Czapek agar.

Morphology. The conidiophores arise from the basal felt. They are smooth-walled and septated, with a tendency for the ramuli and metulae to be somewhat swollen. The whole structure forms a compacted head, typical of the section. There is usually a short (15 μ) appressed branch bearing metulae at the same level as those of the main axis. The metulae tend to widen upwards; they are approximately 10 μ long and bear numerous rather wide sterigmata (8 $\times$ 3·5 μ). The spores are borne in short tangled chains. The spores appear elliptic when young and still attached to the sterigmata, but as they mature they become sub-globose, or even globose, somewhat uneven in size, averaging 2·5-3 μ, with smooth walls.

These isolations when grown on Raulin-Thom solution produce phenolic substances which on addition of ferric chloride give the typical bluish crimson colour test (Clutterbuck *et al.*, 1932). According to Smith (1946) all freshly isolated strains of this series give this characteristic reaction.

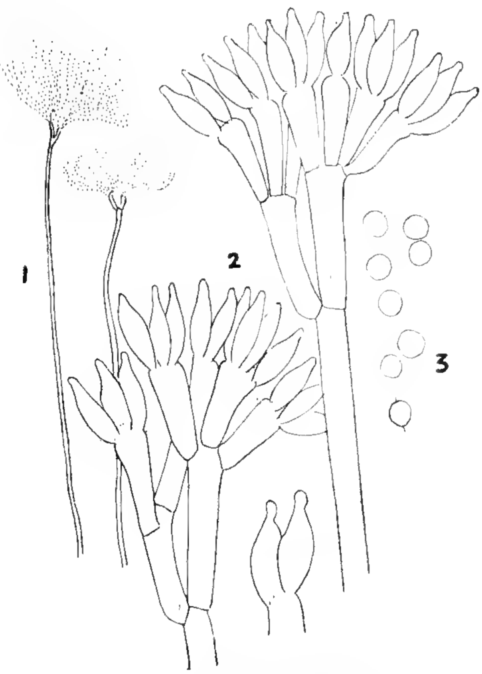

FIG. 25.—*P. brevi-compactum* Dierckx. 1. Habit sketch. 2. Details of penicillus, $\times$ 600. 3. Spores, $\times$ 600.

The features of diagnostic significance are:

(1) The compact character of the penicillus.

(2) The restricted growth on all three media.

(3) The buff to olive - grey buckled reverse.

Isolated from B horizon of the sandy podsol at Frankston, Victoria, and from the Mallee soils, Mildura, at 6 in. level.

THE ASYMMETRICA-LANATA

Penicillium lanosum Westling. Archiv. für Botanik, 11, 1911.

Malt. In 14 days the colony diameter is 6 cm. The mealy to floccose upper surface is at first pale shades of green, and later it deepens to lily green (XLVII), then towards deep olive-grey, with a faint zonation. There is a conspicuous white margin.

The reverse is cream to clay colour at the centre, with the green sporing shades showing through.

Czapek. The colony diameter is 3·5-4 cm. in 14 days. The upper surface is floccose, lily green at the centre, with bluish grey-green shades towards the edge; later it shows slate-olive tones and in age pink colours appear in the mycelium. There is a narrow white margin.

The reverse is only very slightly buckled; peach shades to buff pink (XXVIII) develop at the centre; in some strains, yellowish olive (XXX) tones develop.

Raulin. In 14 days the diameter is 4·5-5 cm. The upper floccose surface is pale grey-green, and passes outwards to paler colours (puritan grey, XLVII). Small colourless or pale pink exudate droplets occur.

The reverse is only slightly buckled. At first it is cream, with later pale pinkish buff to vinaceous buff (XL) colours; in age, greenish yellow to brown shades may appear.

Morphology. The conidiophores vary greatly in length; the shorter arise from trailing hyphae, the longer from hyphae close to the substratum. Their walls are usually roughened, and they bear rather irregular penicilli. The branches occur at various levels. Sometimes a branch arises rather low on the conidiophore, or the axis may fork or remain unbranched. The branches usually bear a few metulae, occasionally six to eight may form the whorl; they are 10-12 μ long, and on their slightly inflated tips the sterigmata arise. They measure 5-8 μ long, and they narrow somewhat abruptly at the spore origin. The spore chains are short and rather tangled. The spores are globose or sub-globose, 2·5 μ, and the wall is finely punctate and lightly tinted.

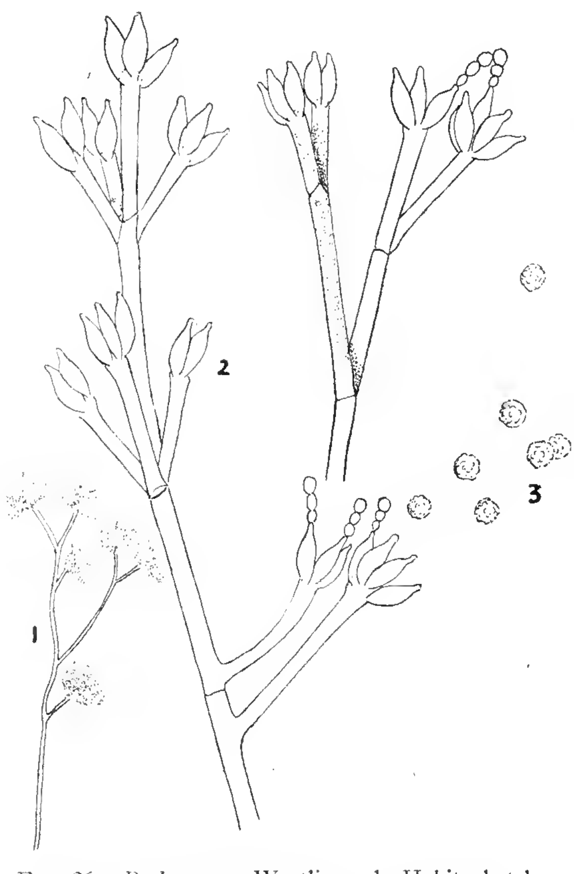

FIG. 26.—*P. lanosum* Westling. 1. Habit sketch. 2. Details of conidiophore and penicillus, × 600. 3. Spores, × 600.

The features characteristic of this species are:

(1) The lack of any pronounced pigment development on the three media used.

(2) The irregularly branched, asymmetric penicilli with branches arising at any level of the conidiophore.

(3) The comparatively small spore.

Isolated from a mountain loam (Bogong High Plains, Victoria) supporting a dense sward of *Poa caespitosa.* The fungus was recovered from the B horizon, between 9-14 in.

THE FASCICULATA

Key to the Fasciculata

1.	Sclerotes present	*P. Gladioli*
1.	No sclerotes formed	2.
2.	Complex coremia formed	3.
2.	Coremia absent, fascicles of conidiophores usually present	4.
3.	Coremia bearing individual penicilli in both lateral and apical positions	*P. granulatum*
3.	Coremia with clavate heads on which the individual penicilli are not readily discernible	*P. claviforme*
4.	Fascicles of conidiophores reduced or absent on agar media	5.
4.	Fescicles typically present on agar media	7.
5.	Cultures with a pronounced 'musty' odour	*P. expansum*
5.	Odour not pronounced	6.
6.	On all media, the colour of the sporing surface in age dark olive-grey	*P. puberulum*
6.	On all media, the colour of the sporing surface not so dark—close to lily green	*P. Urticae*
7.	Sporing surface on all media bluish grey-green	*P. Martensii*
7.	Sporing surface on all media green: conidiophores rough-walled ..	*P. viridicatum*

Penicillium Gladioli Machacek. Quebec Soc. for Prot. of Plants, Ann. Rept., 19, 1928.

Malt. The colony diameter at 14 days measures 4 cm. The surface is floccose, and is essentially white until the sclerotes form. It then becomes pale to light pinkish cinnamon (XXIX) in the central regions; the colour finally spreads across the colony surface; pale or colourless exudate droplets may form.

The reverse is cream to white, and in age may become pinkish cinnamon (XXIX).

Czapek. The colony diameter measures 2·5-3 cm. at 14 days. The surface is markedly floccose and white; it later becomes pale to light pinkish cinnamon

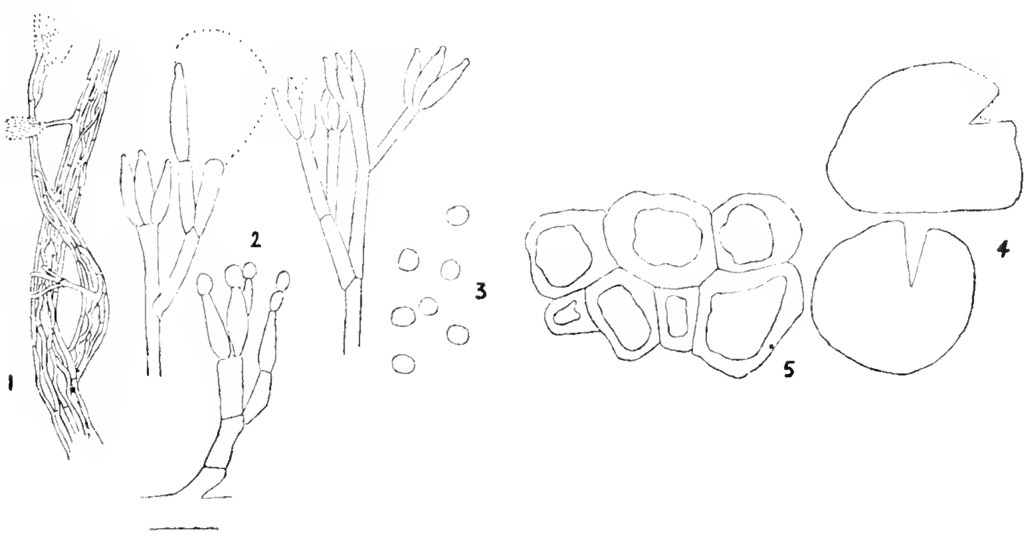

Fig. 27.—*P. Gladioli* Machacek. 1. Ropes with conidiophores, × 50. 2. Details of penicillus, × 460. 3. Spores, × 460. 4. Sclerotes, × 50. 5. Cells of sclerote, × 460.

(XXIX) in the central regions; colourless or pale cinnamon exudate drops usually present. The margin is uneven, more or less fan-like in development.

The reverse is buckled and the colour is much as on malt.

Raulin. The rate of growth and characters of the colony are as for Czapek.

Morphology. The conidiophores form very sparsely on all of the three media, and our cultures never show any green shades after incubation at 16° C. or at 25° C. They vary in length, sometimes being very short (20 μ), but are usually longer. They arise mostly from mycelial ropes, and occasionally from individual hyphae; we have never observed true fascicles or coremia. The axis of the conidiophore may bear one or two branches subtending metulae 10-12 μ long. The sterigmata are mainly 10 μ long, occasionally longer, and taper towards the sporing tip. The spores form tangled chains; each is elliptic to sub-globose, smooth-walled, 2·5-3 $\mu \times$ 2·5 μ. The sclerotes are found in great numbers, and vary both in size and shape, averaging in our cultures approximately 250 μ. They are pale pinkish cinnamon (XXIX) in colour and hard in texture. The walls are composed of rather unevenly thickened cells approximately 10-15 μ in diameter.

The features of diagnostic significance are:

(1) The abundant formation of sclerotes over a floccose white mycelial mat.

(2) The pale colours of the colony on all three media, even in age.

(3) The formation of ropes from which the conidiophores arise.

(4) The smooth-walled, elliptic to sub-globose spores.

Isolated from Mallee soils at a depth of 8-18 in.

Penicillium granulatum Bainier. Bul. Soc. Mycol. France, 21, 1905.

Malt. The colony diameter is 3 cm. in 14 days. The surface is tufted and floccose, andover to slate green (XLVII), with a narrow white margin. Pale exudate drops form all over the surface. The colony is characterized by the very conspicuous coremia which are often formed in zones.

The reverse is coloured ochraceous orange to ochraceous buff (XV). The outline of the colony is irregular, due to the development of fan-like extensions beyond the general growth.

Czapek. The colony measures 2·8 cm. in 14 days. The surface is tufted, due to the conspicuous coremia, similarly coloured to that on malt agar, with an irregular outline as before.

The reverse is ochraceous orange at the centre, fading outwards to aniline or sulphine yellow (IV).

Raulin. The growth rate is comparable to that on Czapek agar. The surface character and colour are also similar; numerous small exudate drops are present over the surface.

The reverse is slightly buckled, tawny to russet or cinnamon brown (XV).

Morphology. The conidiophores may arise singly from surface hyphae, but the colony surface support numerous coremia, formed by fascicles of fruiting hyphae grouped together to form the *Stysanus*-like masses. These are branched structures, and the rough-walled conidiophores arise from the upper parts. Each bears one or two adpressed branches, from which the roughened metulae arise. They are 8-12 μ, sometimes longer, with numerous sterigmata in verticils at their ends. The sterigmata are rather narrow, about 10 μ long, and from them arise tangled chains

of spores. The spores are strongly elliptical when young, and tend to retain this shape when mature, or they may become sub-globose; they measure 2·5-3 μ in their long axis.

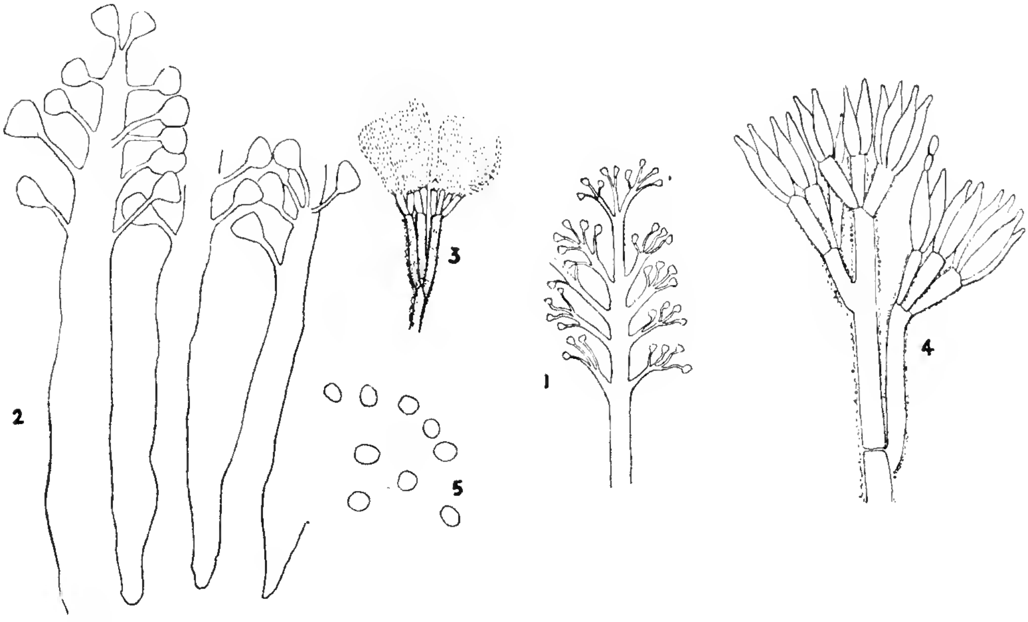

FIG. 28.—*P. granulatum* Bainier. 1. Sketch of coremium. 2. Portion of coremium, × 65. 3. Penicillus, × 65. 4. Details of penicillus, × 600. 5. Spores, × 600.

This isolation has a very strong fragrant odour when grown on agar media, variously identified as aniseed- or camphor-like.

The diagnostic features of significance are:

(1) The profuse development of complex coremia.
(2) The roughened conidiophores.
(3) The elliptic conidia.
(4) The fragrant odour.

Isolated from the A horizon of the sandy podsol at Frankston, Victoria.

Penicillium claviforme Bainier. Bul. Soc. Mycol. France, 21, 1905.

Malt. The colony diameter measures 6 cm. at 14 days. The surface is floccose, and at first there are no signs of coremial formation. The colour is bluish green and approximates artemisia or lily green (XLIII); later it darkens towards slate olive. At 14 days, coremia are visible, particularly in the younger parts of the colony, at a radial distance from the centre of 1·5 cm. and beyond, and appear as erect, whitish, *Isaria*-like mycelial columns. Under a hand lens, however, smaller coremial structures can be discerned closer to the centre, in zones beneath the floccose surface. From above, they appear as round green knobs, but when seen from the side they show distinct white stalks, terminating in the rounded green sporing heads. The margin of the colony is rather thin and white.

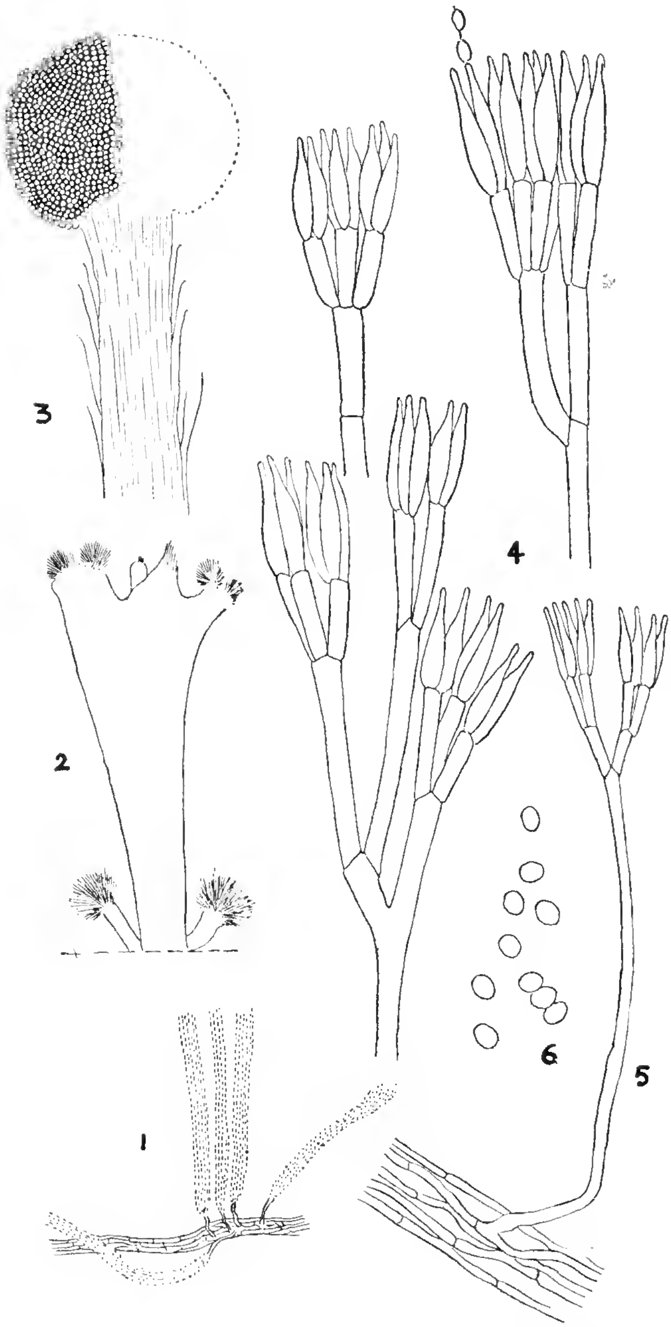

Fig. 29.—*P. claviforme* Bainier. 1. Habit sketch of young growth. 2. Sketch of short-stalked coremia and Isarial-type of coremia. 3. Short coremia, × 65. 4. Details of conidiophores, × 600. 5. Rope and conidiophore, × 290. 6. Spores, × 600.

The reverse, in the early stages, is a clear red, passing to morocco red (I); at 14 days it is hessian brown at the centre, with lighter shades, such as dragon's blood red (XIII), beyond. The colour is somewhat zoned, the zones corresponding to regions of coremial formation. The margin is pink, and the pink colour diffuses into the medium.

Czapek. The growth rate is restricted, the colony diameter at 14 days measuring 2 cm. The surface appears floccose, and at first shows the same general bluish green shades as on malt agar. At 14 days, the surface is studded with young, erect, *Isaria*-like coremial columns. These are buff to cream, except at the growing tips, which appear white. Many of them have colourless exudate droplets adhering to the upper part. With a hand lens, smaller coremial heads, similar to those described on malt, can be seen. There is a narrow, thin and rather irregular white margin.

The reverse is plane, dark olive to deep olive (XL), bounded close to the margin by a narrow ring of old gold.

Raulin. Growth is also restricted, the colony diameter at 14 days being 3 cm. The surface in the early stages is cottony to floccose, and lily green. Later, the central region

becomes covered with numerous erect and variously lobed coremial structures, with the buff-coloured bases and white tips which characterize similar structures on Czapek agar. Beyond this region, there is a dense stand of the short round-headed green coremia, giving a deep slate-green colour (XLVII) to the surface in this area. The margin is paler, bluish green, with developing *Isaria*-like coremia scattered through it.

The reverse is plane, at first mummy brown to Prout's brown (XV), later becoming olivaceous black (XLVII) with an old gold rim and a thin, irregular, white margin.

Morphology. In the early growth on malt agar, many conidiophores arise from trailing ropes of hyphae. They are from 50 to 100 μ in length, and support penicilli with spore heads in narrow columns 200-250 μ long. Later, coremia form; these are not as abundant on malt as on Czapek or Raulin agars. The first formed coremia are short, stalked structures, little elevated from the substratum. They are distinctly clavate, the rounded heads being supported on a short, white stalk. The diameter of the head may be 200 μ or more, that of the stalk approximately 100 μ. Later, more conspicuous coremia develop, especially on Czapek and Raulin agars. They are of the '*Isarial*' type described and figured by Raper for *Penicillium clavigerum* Demel. These are erect, fasciculate structures, 3-4 mm. or more, buff coloured except at their tips, which are white. These tips are often pointed, but sometimes they become flattened and branched in an irregular way; ultimately sporing heads form over their upper surfaces. On old malt slopes, the pattern of the sporing heads on these buff-stalked coremia is very characteristic; short quadrangular columns of spores radiate out in an umbel-like manner all over their tips.

The penicilli formed on individual conidiophores are variable in type; many of them are asymmetric, with one or more branches arising a short distance behind the main axis, and often extending beyond it; other penicilli are quite symmetrical in form. The metulae are in groups of two to four or more; they are 8-10 μ long, and bear whorls of crowded sterigmata. These resemble those of the *Biverticillate-symmetrica*; they are long (10-12 μ) and narrow, and taper to the conidium-bearing tips. The spores are elliptic, averaging 3×2 μ, and smooth-walled. It is impossible to distinguish the individual penicilli that constitute the fertile surface of the clavate coremia. The parts are so crowded together that there appears to be formed a continuous surface of sterigmata from which chains of conidia are produced, which are at first adherent to one another, but later split into the quadrangular groups already described.

This description has been based on our isolation L31. Some difficulties present themselves in assigning it to a particular taxonomic position. The clavate coremia and the hymenial-like surface formed by the sterigmata suggests affinities with *Penicillium claviforme* Bainier, but the presence of the *Isarial*-like coremia in the same colonies, and the type of growth on malt agar, recall *P. clavigerum* Demel. as understood by Raper. The *Isarial*-like coremia eventually form one to many sporing caps on their extremities, with the typical hymenial surface characteristic of *P. claviforme,* and L31 represents a strain of this species.

The features of diagnostic significance are:

(1) The fasciculate character of the colony surface.

(2) The presence of clavate and *Isarial*-like coremia.

(3) The occurrence of asymmetrical and symmetrical penicilli in the early stages of growth.

(4) The interlaced penicilli over the surface of the clavate heads.

(5) The elliptic, smooth-walled spores.

Isolated from litter under *Banksia marginata* and *Leptospermum myrsinoides*, growing on the sandy podsol at Frankston, Victoria.

Penicillium expansum Link. Observationes, 1809.

Malt. The colony diameter measures 5·5 cm. in 14 days. The surface is velvety at first, then becomes mealy or powdery, artemisia to lily green, zoned (XLVII), with a narrow white margin.

The reverse at the centre shows ochraceous buff tints, greenish outwards due to spore colour showing through, close to citrine (IV), sometimes forming a zoned pattern.

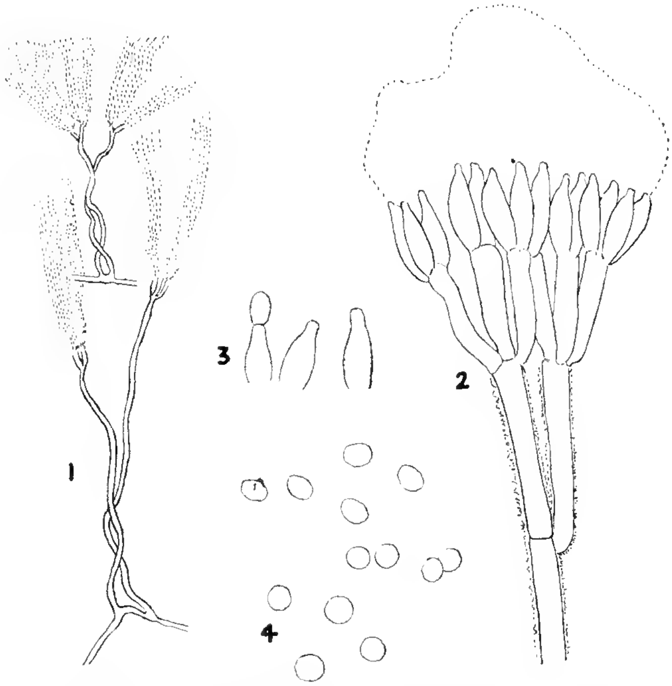

FIG. 30.—*P. expansum* Link. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Sterigmata, × 600. 4. Spores, × 600.

Czapek. The colony diameter at 14 days is 3-3·5 cm. The surface is mealy, lily green, becoming slate olive (XLVII), zoned, with distinct bluish glaucous tints (XLII) near the narrow white margin.

The reverse is not, or only slightly, buckled, drab, with buff tints at the centre; later, in some isolations, vinaceous tints develop.

Raulin. The rate of growth is similar to that on Czapek agar. The surface is very mealy to floccose, with the sporing colour much as for Czapek, with marked zonation, and a narrow white margin. Small colourless exudate drops are present.

The reverse is slightly buckled. Some isolations develop an olive lake colour (XVI), others show a much deeper colour, yellow ochre to ochraceous orange (XV); some also develop vinaceous shades among the ochraceous orange.

Morphology. At the edge of the colony in some isolations slight fasciculation is evident; two or three condiophores arising close together twist among themselves to form small fascicles, but the great majority, and in some strains all, the conidiophores arise independently close to the substratum. All isolations, however, when inoculated into apples, produced the typical 'expansum' rot, together with characteristic coremia. The conidiophores are long, typically rough-walled, with one or two adpressed branches close to the apex; these bear two to five metulae 10-12 μ long and bearing long twisted columns of spores. The spores are elliptic in youth, tending to become sub-globose when mature, mostly 3-3·5 μ in diameter, sometimes larger, smooth or finely punctate, tinted in mass.

The features of diagnostic significance are:

(1) The strong and characteristic 'mouldy' smell of the cultures.

(2) The reduction of fasciculation when grown on agar media, but the formation of coremia when inoculated into the apple.

(3) The dull green shades of the sporing surface, and the ochraceous orange reverse on Raulin's agar.

Isolations have been obtained from the B ('coffee rock') and C horizons of the sandy podsol at Frankston, Victoria, and from the Mallee soil (Mildura) at 6 in. and 12 in. levels.

Penicillium puberulum Bainier. Bul. Soc. Mycol. France, 23, 1907.

Malt. The colony diameter in 14 days is 4 cm. The surface is at first velvety, but later tends to become mealy, slate olive (XLVII), zoning outwards, narrow white margin.

The reverse is buff coloured right at the centre, with the green sporing shades showing through on an uncoloured background in a zoned pattern; white at the margin.

Czapek. The colony diameter measures 5 cm. at 14 days. The surface is mealy, slate olive at the centre, passing into lily green and thence to a ring of light celandine green (XLVII), with pale exudate drops, and sometimes becoming zoned in heavy ridges. There is a broad white margin.

The reverse is not buckled, and is pale with buff tints.

Raulin. The colony diameter in 14 days is 4-5 cm. The surface is felty, and shows the same range of colours as on Czapek agar; small pale exudate drops are present, and there is a narrow white margin.

The reverse is only slightly buckled at the centre; the colour is Saccardo's umber to tawny olive (XXIX); cream beyond.

Morphology. The conidiophores arise mostly from creeping hyphae; at the edge of the colony a small amount of fasciculation is present. The conidiophores are long and slightly roughened, with one or two branches arising close to the apex. These bear whorls of two to five metulae, 10-15 μ long, and with rather swollen ends. The sterigmata, 10-12 μ long, bear the spores in long tangled chains. The spores are sub-globose, smooth-walled, 3-3·5 or even 4 μ in diameter.

The features of diagnostic significance are:

(1) The reduced amount of fasciculation present; otherwise this form is close to *P. cyclopium*, but

(2) The colour of the sporing surface in age is darker, becoming almost dark olive-grey (LII).

Isolated from the C horizon of the sandy podsol at Frankston, Victoria.

Penicillium Martensii Biourge. La Cellule, 33, 1923.

Malt. The colony diameter in 14 days is 5-6 cm. The surface is velvety at the centre, powdery or mealy nearer the margin, deep bluish grey-green (XLII), with a white margin. Numerous colourless exudate droplets may be present. The surface becomes darker and zonate in age.

The reverse is yellowish citrine (XVI) to chalcedony yellow (XVII).

On malt slopes the reverse develops a pinkish colour in age.

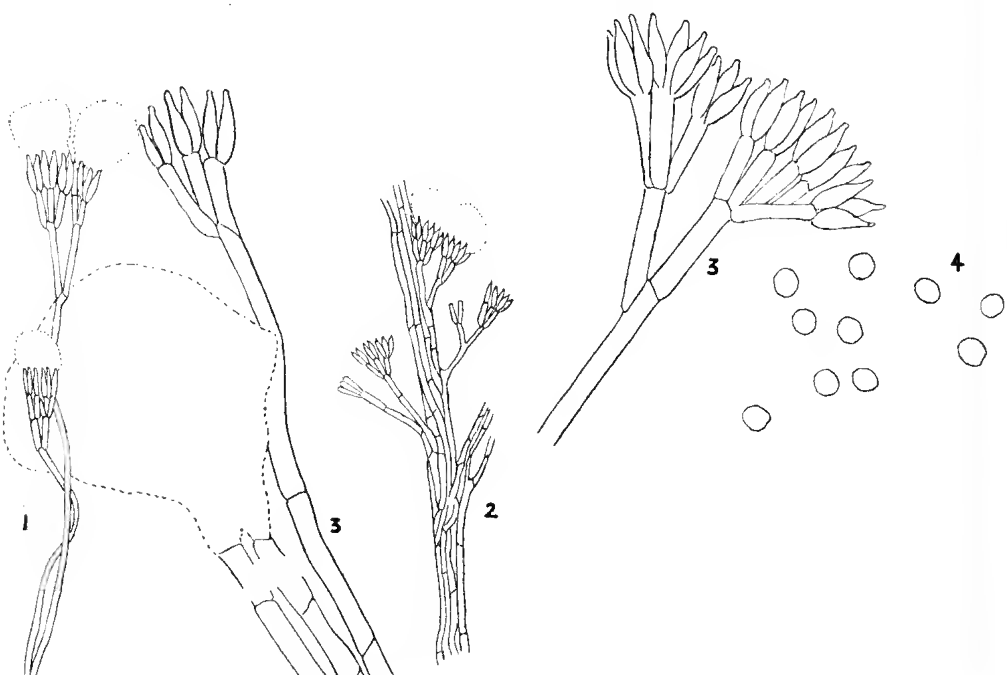

FIG. 31.—*P. Martensii* Biourge. 1. and 2. Habit, × 55. 3. Details of penicillus, × 500. 4. Spores, × 500.

Czapek. The colony diameter in 14 days is 4-5 cm. The surface is very floccose at the centre, deep dark bluish grey-green (XLII), exudate droplets pushing through the felt form round pimple-like areas. There is a broad white margin.

The reverse is slightly buckled, the central region is light ochraceous salmon, passing into light ochraceous buff (XV); margin white.

Raulin. The rate of growth is similar to that on Czapek. The surface is floccose, deep bluish grey-green at the centre, beyond pale glaucous blue (XLII), with a narrow white margin. Many pale yellow droplets push through the felt.

The reverse is scarcely buckled, at first apricot buff (XIV), later deepening to etruscan or ochre red (XXVII), with some zoning of the colour.

Morphology. The smooth-walled conidiophores arise singly from trailing hyphae, or grouped together into fascicles. Sometimes the amount of fasciculation is reduced, and the single conidiophores predominate. The penicilli form complex heads; they show one or more branches in addition to the main axis (approx. 15 μ long). The metulae, three to four in the whorl and about 10 μ long, bear the sterigmata, which narrow at their ends and bear long massive tangled chains of spores. The spores are smooth-walled, elliptic to sub-globose, approximately $3 \times 2{\cdot}5\ \mu$.

The features of diagnostic significance are:

(1) The fasciculate sporing surface.

(2) The bluish grey-green colour of the sporing surface.

Isolated from the C horizon of the sandy podsol at Frankston, Victoria, and from the Mallee soil at a depth of 12 in.

Penicillium Urticae Bainier. Bul. Soc. Mycol., France, 23, 1907.

Malt. The colony diameter is 4·5-5 cm. at 14 days. The surface is floccose to granular, shading from lily green or deeper (XLVII), with a narrow white margin.

The reverse shows a drab greenish background in which orange vinaceous (XXVII) to orange cinnamon (XXIX) shades appear, sometimes darkening to mikado brown (XXIX). These colours are shot through the reverse, and may form a ring towards the edge of the colony.

Czapek. The growth is somewhat retarded and measures 3·5-4 cm. at 14 days. The surface is granular, artemisia to lily green (XLVII), with a very broad white margin. A vinaceous to brown colour diffuses into the medium.

The reverse is slightly buckled, and is vinaceous pink to vinaceous russet (XXVIII).

Raulin. The colony grows at the same rate as on malt. The surface is floccose to granular, artemisia to lily green (XLVII), with a narrow margin.

The reverse is radially buckled, and is in the same colours as on Czapek agar, but deepening further to burnt umber or, in patches, even darker (XXVIII).

Morphology. The smooth-walled conidiophores are either grouped into fascicles or arise singly and bear complex penicilli. The branching of the heads may be irregular, so that the sterigmata arise at different levels. The secondary branches are 10-15 μ long, and bear two to four short metulae, 5-7 μ long. The sterigmata are also short, approximately 5 μ, and bear rather tangled columns of spores. The spores are elliptical, 2·5-3 μ in their long axis, smooth-walled.

The features of diagnostic significance in the series are:

(1) The lighter sporing colour.
(2) The unequal branching in the penicillus.
(3) The short metulae and sterigmata.

Isolated from litter under *Leptospermum myrsinoides* when the sample was poured with malt agar at 40° C., 60° C. and 80° C.

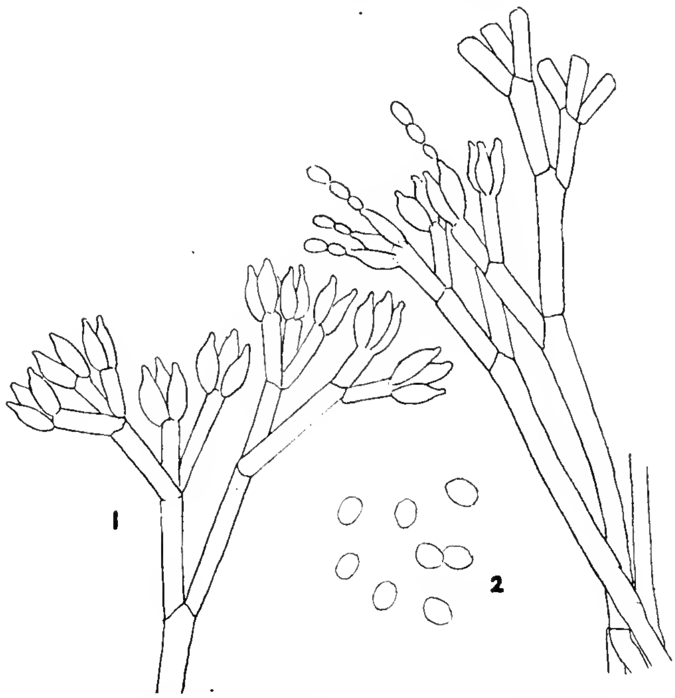

FIG. 32.—*P. Urticae* Bainier. 1. Details of conidiophore and penicillus, × 600. 2. Spores, × 600.

Penicillium viridicatum Westling. Archiv für Botanik, 11, 1911.

Malt. The colony diameter in 14 days is 4·5 cm. The surface appears powdery and zoned, lily green (XLVII), with a narrow white margin; sometimes the centre becomes overgrown with yellow and white cottony hyphae.

The reverse develops dark olive buff shades (XL) with a paler centre. A coloured area develops in the surrounding medium, forming a ring from 0·5 to 1 cm. wide around the colony; it is pale vinaceous brown (XXXIX).

Czapek. The colony diameter measures 4 cm. in 14 days. The surface appears floccose and somewhat tufted, the tufts tending to occur in zones; lily green (XLVII), with numerous colourless exudate droplets and a broad white margin.

The reverse is only slightly buckled, brownish vinaceous (XXXIX) to fawn colour (XL), zoned with a lighter colour.

Raulin. The rate of growth is similar to that on Czapek. The surface is lily green to slate olive (XLVII), with pale yellow or clear exudate drops. Sometimes the centre shows a white mycelial overgrowth, and there is a broad white margin.

The reverse is slightly buckled, rather variable in colour, towards kaiser brown (XIV) or paler, but deeper tones close to haematite red (XXVII) develop later in irregular zoned areas.

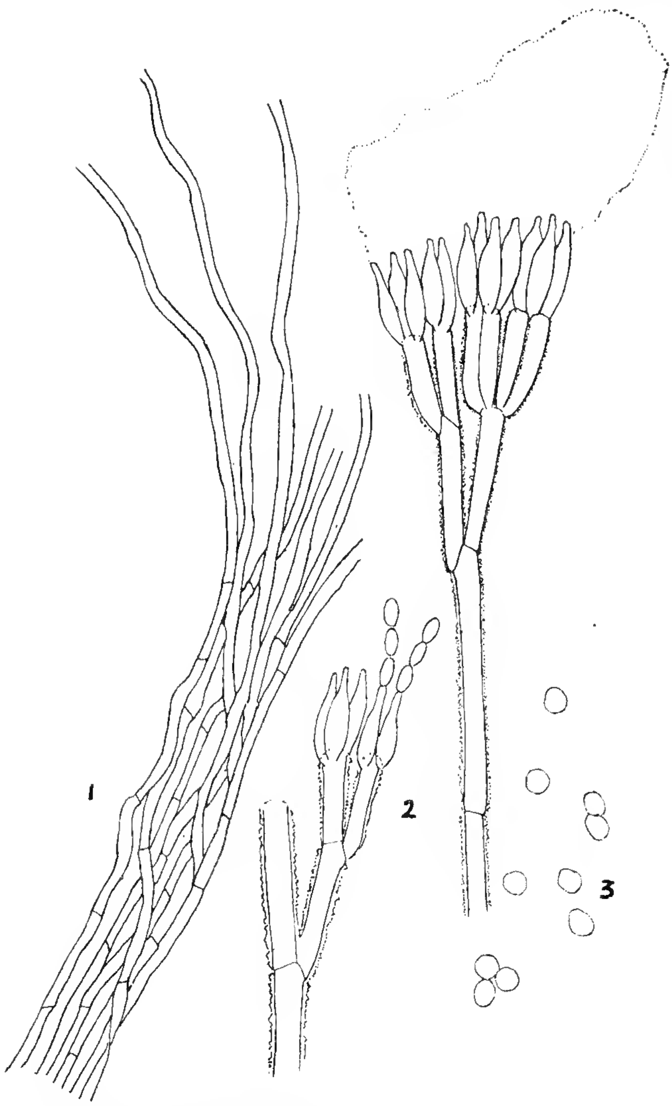

FIG. 33.—*P. viridicatum* Westling. 1. Young fascicle, × 600. 2. Details of penicillus, × 600. 3. Spores, × 600.

Morphology. The surface of the colonies in age becomes tufted, due to the grouping of the fruiting hyphae into fascicles; the conidiophores separate at the ends of these fascicles, others arise directly from aerial hyphae. Each conidiophore is long, with rough walls, usually once branched close to the apex. The metulae are rough (8-10 μ), and bear several fairly long sterigmata (8-10-12 μ). The spore chains form large sporing heads of tangled, irregular columns. The spores are elliptical when first formed, and in chains, but become sub-globose when mature, 3-3·5 μ × 2·5-3 μ. The walls are delicately roughened and lightly tinted.

The features of diagnostic significance are:

(1) The occurrence of fascicled conidiophores, together with many simple ones in the sporing surface.

(2) The rough-walled conidiophores and metulae.

Isolated from the B horizon ('coffee rock') of the sandy podsol at Frankston, Victoria.

THE BI-VERTICILLATA-SYMMETRICA

KEY TO THE BI-VERTICILLATA-SYMMETRICA

1.	Ropes of hyphae absent	2.
1.	Ropes of hyphae present	7.
2.	Spores elliptic and roughened	3.
2.	Spores globose or sub-globose	4.
3.	Spores elliptic and rough, reverse on malt and Czapek agars, pale coloured	*P. rugulosum*

E

3.	Spores elliptic to sub-globose, rough to almost smooth, reverse on malt and Czapek agars in typical isolations; red in youth, deepening to red-brown shades	*P. purpurogeneum*
4.	Growth markedly restricted on Czapek agar	5.
4.	Growth not so restricted	6.
5.	Reverse on malt and Czapek in reddish shades	*P. purpurogeneum* (some isolations)
5.	Reverse pale on all three media	*P. diversum*
6.	Growth not restricted at least on malt or Raulin agars. Spores globose, small, 2-2·5	*P. rubrum*
7.	Growth restricted on all three media, spores elliptic and smooth ..	*P. islandicum*
7.	Growth not so restricted	8.
8.	Spores globose and echinulate	*P. verruculosum*
8.	Spores elliptic to sub-globose and smooth	*P. funiculosum*

Penicillium rugulosum Thom. U.S. Dept. Agr. Bur. Anim. Ind. Bul., 118, 1910.

Malt. The colony diameter at 14 days is 3 cm. The surface is velvety, deep greyish blue-green (XLVIII) with the sporing surface spread uniformly over the colony, covered with a thin but close overgrowth of white hyphae, practically to the abrupt margin. Small colourless exudate drops may be present.

The reverse is slightly buckled and close to warm buff in colour (XV).

Czapek. The colony diameter at 14 days is 3·5-4 cm. The surface is mainly velvety with the conidial structures rather irregularly developed, more abundant outwards, light celandine green to deep glaucous grey (XLVIII) with a narrow white margin, colourless exudate drops usually present.

The reverse is slightly buckled, at least at the centre; at first pale, then generally cream with ochraceous-salmon localized areas radiating through it.

Raulin. The colony diameter at 14 days is 3 cm. The type of surface is similar to that formed on Czapek, with conidial structures much reduced, the colony remaining generally white with pale greenish blue tints towards the margin; the margin is abrupt.

The reverse is much buckled in shades of buff to definite yellow shades close to antimony yellow or yellow ochre (XV).

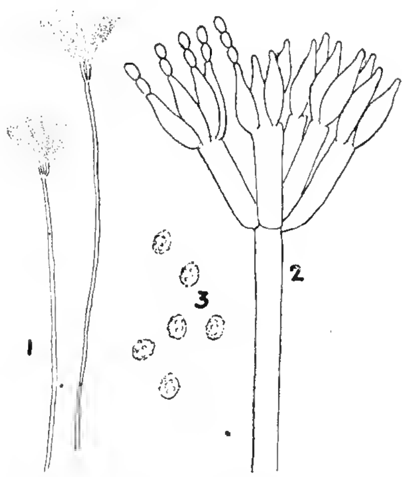

FIG. 34.—*P. rugulosum* Thom. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

Morphology. The smooth-walled conidiophores arise from the basal felt. They bear a whorl of metulae (12 μ) which are sometimes spreading and these support the rather short sterigmata (7-9 μ), which are tapered at the conidial bearing ends. The conidia are borne in short tangled heads; each conidium is elliptic, about 2·5 × 3 μ, with a roughened wall.

The features of diagnostic significance are:

(1) The restricted growth on all three media.
(2) The velvety type of surface.
(3) The elliptic roughened spores.

Isolated from a mountain loam of the Bogong High Plains, Victoria, at the B_3 level (18-32 in.).

Penicillium diversum Raper and Fennell. Mycologia, 40, 1948.

Malt. The colony diameter in 14 days measures 4-4·5 cm. The surface is velvety, faintly zoned and uniform in colour, close to lincoln green (XLI), bordered by a narrow yellow rim with a submerged margin (2-3 mm.) beyond the coloured area. Under the low power of the microscope, yellow encrusted hyphae are seen to form a loose network over the surface.

The reverse is slightly buckled at the centre plane, elsewhere pale cream (XVI).

Czapek. The growth on this medium is so restricted that it is difficult to describe any salient features. The diameter in 14 days is about 3-4 mm. The surface is covered with sporing heads, giving a lincoln green (XLI) colour. The margin is irregular and white.

The reverse is colourless, with the green sporing shades showing through.

Raulin. Colony diameter at 14 days is 2·5 cm. The surface is velvety and very similar in character to that described for malt agar. The reverse is buckled and buff-yellow at the centre (IV), paler and flat beyond, with a rather uneven margin.

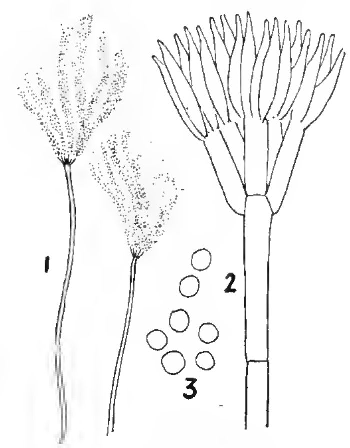

FIG. 35.—*P. diversum* Raper and Fennell. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

Morphology. The conidiophores arise from the basal felt. They are smooth-walled or sometimes the walls are slightly roughened. The penicilli are of the typical bi-verticillate symmetrical type. The metulae are 8-10 μ long and bear crowded and somewhat appressed sterigmata about 10 μ long and tapering to the conidial bearing tube. The spores are borne in loose tangled heads; the conidia are sub-globose, small, about 2 μ in diameter and smooth-walled.

The features of diagnostic significance are:

(1) The restricted growth on all media, but pronouncedly so on Czapek agar.

(2) The velvety surface with yellow hyphal overgrowth.

(3) The small, smooth, sub-globose spores.

Penicillium purpurogenum Stoll. Beit. zur Morph. und Biolog. Charact. von Penicilliumarten Wurzburg, 1904.

Malt. The colony diameter measures 2·7 cm. in 14 days. The surface is velvety, pea to sage green (XLVII), with traces of orange mycelium towards the centre, pinard yellow (IV) outwards, with a narrow white margin.

The reverse is buckled radially, honey yellow (XXX) or clay colour (XXIX).

Malt slopes incubated at 25° C. show a sporing surface close to slate olive (XLVII) with orange red mycelium showing through the green area and forming the margin of the colony, the colour of which approximates to salmon orange or orange chrome (II).

The reverse is the same brilliant colour and the pigment diffuses into the medium.

Czapek. The colony diameter measures 1·8 cm. in 14 days. The surface is velvety and shows a medley of colours, mostly yellow-green (citron green (XXXI)), with deeper green areas and a narrow pale yellow margin. Small colourless exudate drops may be present over the surface.

The reverse is in purplish red shades (XXVII) and slightly buckled; the purplish pigment diffuses into the surrounding agar.

Raulin. The colony measures 2 cm. in 14 days. The surface is slightly floccose and repeats the colours as for Czapek.

The reverse is buckled and tends to crack so that the orange-yellow basal felt shows through. The general colour of the reverse is in shades of brownish drab (XLV).

Morphology. The conidiophores vary in length according to their point of origin. If from trailing hyphae, they are about 50 μ long, but many arise from the substratum and are over 100 μ long. They are smooth-walled and septated. The penicilli are of the typical bi-verticillate and symmetrical type with a whorl of metulae 10-12 μ long, surmounted by clusters of sterigmata about 10 μ in length. The spores are borne in short tangled brush-like heads, about 50 μ in height. The spores are elliptic to subglobose, 2-2·5 × 2 μ, almost smooth-walled and sometimes apiculate.

Description illustrative of isolation PVC_3.

The features of diagnostic significance are:

(1) The velvety or near velvety surface.

(2) The restricted growth on all three media.

(3) The purplish red reverse on Czapek.

(4) The brilliant salmon orange colony margin on malt slopes incubated at 25° C.

Isolated from a mountain loam of the Bogong High Plains, Victoria, at the B_3 level (18-22 in.).

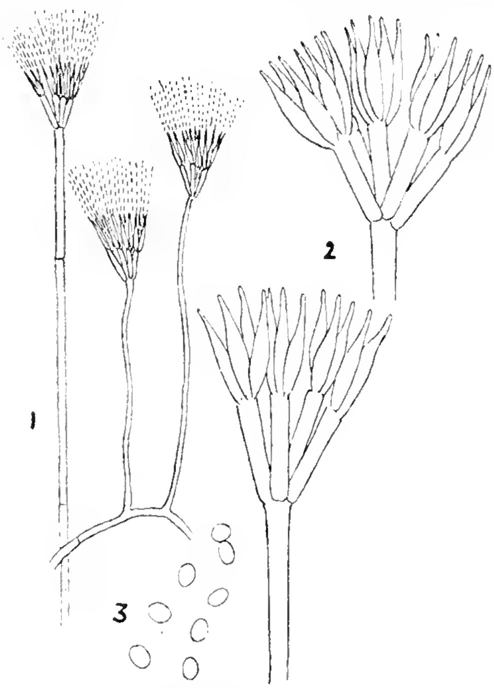

FIG. 36.—*P. purpurogenum* Stoll. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

Penicillium purpurogenum Stoll.

Malt. The surface is velvety, lincoln green (XLI) or darker with creamy-yellow margin and sometimes a development of yellow hyphae at centre of colony. Pale yellow exudate drops may be present. Malt slopes differ from those of PVC_3 in the more uniform green colour and paler margin.

The reverse is plane. For M1B5, in youth, particularly at 25° C., it is red, but later deepens to a colour close to burnt umber (XXVIII). For 6B512 it is at the centre dark vinaceous to hydrangea red (XXVII); the rest is cream with areas of buffy citrine (XVI).

Czapek. Colony diameter at 14 days measures 0·75 cm. The surface is velvety and coloured much as on malt. The margin is abrupt and uneven.

The reverse is plane; in M1B5 it is ox-blood red to garnet brown (I), fading to the margin; in 6B512 it is paler, with suggestion of red colour.

Raulin. The surface is velvety with the central area raised in the form of an umbo; the green sporing colour close to artemisia green (XLVII), deepening in age, with a distinct pale yellow rather broad rim and abrupt margin.

The reverse is plane, madder brown or deeper (XIII); sometimes the red colour diffuses into the medium.

Morphology. The microscopic features are similar to those described for PVC_3. However, the spores are larger, averaging $3{\cdot}5 \times 2\text{-}2{\cdot}5\ \mu$, with the walls roughened.

Description illustrative of isolations M1B5 and 6B512.

Isolated from the B horizon of the sandy podsol at Frankston, Victoria, and from the Mallee soils (Mildura) at 12 in. level.

Penicillium rubrum Stoll. Beit. zur morpholog. und biolog. charackt. Penicillium-arten Wurzburg, 1904.

Malt. The colony diameter measures 5 cm. in 14 days and continues to increase with time up to 7 cm. The surface is strictly velvety, in shades of lily to artemisia green (XLVII); in later growth conspicuously zonate with a narrow abrupt white margin.

The reverse is plane, in purplish vinaceous shades (XXXIX), deeper outwards, with zonation lines evident and narrow cream margin.

Czapek. The diameter of the colony is 5 cm. at 14 days. However, the linear spread ceases at that stage and the colony remains approximately at this width. The surface is mainly velvety, but towards the centre may appear slightly floccose; in shades of green rather paler than those developed on malt, and zoned. Small pale exudate droplets may be present and on drying may give a pitted appearance to the surface. The margin is white and rather uneven.

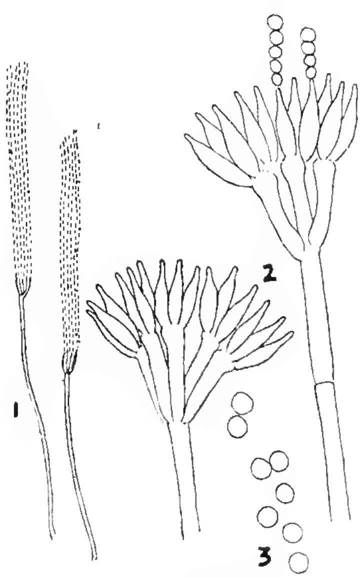

FIG. 37.—*P. rubrum* Stoll. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

The reverse is plane, in russet vinaceous shades (XXXIX), zoned outwards with a white margin.

Raulin. The growth is less on this medium, about 3 cm. in 14 days. The surface is velvety, lily to artemisia green, the surface pitted with small exudate drops and a narrow white margin.

The reverse is very irregularly buckled and lifts away from the medium, army brown to olive brown (XL) with a pale margin and slight yellow discolouration of the medium.

Morphology. The conidiophores arise mainly from the basal felt. They are long and smooth-walled and bear typical bi-verticillate symmetrical penicilli. The metulae average 10 μ in length and they are inflated at the sterigmata bearing ends. The sterigmata are shorter and less tapered than those typical of this group. They average $7\text{-}7{\cdot}5\ \mu$ and they bear the conidia in long narrow columns. The spores are globose to sub-globose, $2\text{-}2{\cdot}5\ \mu$, and smooth-walled.

The features of diagnostic significance are:

(1) The velvety sporing surface.
(2) The smooth-walled conidiophores.
(3) The small, more or less globose, smooth-walled spores.

Isolated from the C horizon of the Frankston sandy podsol, about 50 in. from the ground surface.

Penicillium islandicum Sopp. Monogr., 1912.

Malt. The colony diameter at 14 days measures 2·5-2·8 cm. The surface is very floccose, maize to buff yellow in colour (IV); later the centre becomes pea to sage green (XLVII). Colourless exudate drops may be present.

The reverse is radially buckled, honey yellow (XXX) or clay colour (XXIX), with a narrow pale margin.

Czapek. The colony diameter measures 1·5 cm. in 14 days. The surface is lightly floccose and repeats the same yellow shades as noted for malt agar. Colourless exudate drops may be present.

The reverse is irregularly buckled and is capucine yellow with light orange yellow outwards (III) and narrow white margin.

Raulin. The growth rate is similar to that on malt agar. The surface is sparsely floccose and at first is white to cream coloured (XVI). Later green sporing shades appear at the colony centre, close to gnaphalium green (XLVII), with pale yellow beyond and narrow white margin.

The reverse is irregularly buckled, avellaneous (XL), becoming isabella colour (XXX) with a narrow white margin.

Morphology. The surface of the colony is overgrown with conspicuous ropes of hyphae from which the majority of the short conidiophores arise; many of them are 20-25 μ long and septated. Some conidiophores arise from trailing hyphae and are 75-100 μ long. They bear heads of the typical bi-verticillate symmetrical type. The metulae are 7-10 μ long and they subtend clusters of sterigmata. These are not so slender or tapered as the typical sterigmata for this group, measuring approximately $7 \times 2\ \mu$. The spores are borne in short brush-like heads. They are smooth-walled, elliptical and average about $3 \times 2\ \mu$. The mycelium is encrusted with yellow to orange granules.

The features of diagnostic significance are:

(1) The abundant development of ropes of hyphae from which the conidiophores mainly arise.
(2) The restricted growth on all three media.
(3) The predominantly yellow colour of the colonies.
(4) The elliptic smooth-walled spores.

Isolated from the A horizon of the Frankston sandy podsol.

Penicillium verruculosum Peyronel. I germi atmosferici dei funghi con micelio Padova, 1913.

Malt. The diameter of the colony measures approximately 5 cm. in 14 days. The surface is floccose, deep slate green and zoned (XLVII), passing into a pale yellow rim bounded by a broad white margin.

The reverse shows faint pink shades to occasionally corinthian red (XXVII) at the centre, then green sporing shades showing through cream to white margin.

Czapek. The diameter of the colony measures 4 cm. at 14 days. The surfacc is almost velvety, deep slate green sometimes mixed with yellow hyphae and outlined by a yellow rim with a broad white margin.

The reverse is much as for malt.

Raulin. The rate of growth is comparable to that on Czapek. The surface is deep slate-olive with a deep yellow ring; bright yellow and pink hyphae may be present through the green area, the amount varying with the strain isolated.

The reverse is buckled; pink shades present at the centre in some strains, deepening to ox-blood red (I), yellowing towards the margin.

Morphology. The floccose character of the colonies is due to the development of ropes of hyphae which branch and intertwine over the colony surface. From these ropes the majority of the conidiophores arise. They are of variable length, from 75-250 μ or more. Each bears at its apex a whorl of metulae 8-10 μ long, each subtending a cluster of sterigmata. These are 8-10 μ long, with narrowly tapered conidial bearing tips. The conidia are borne in tangled chains, the whole penicillus forming a spreading head. The spores are globose, 2·5 to 3 μ in diameter, olive-coloured and echinulate.

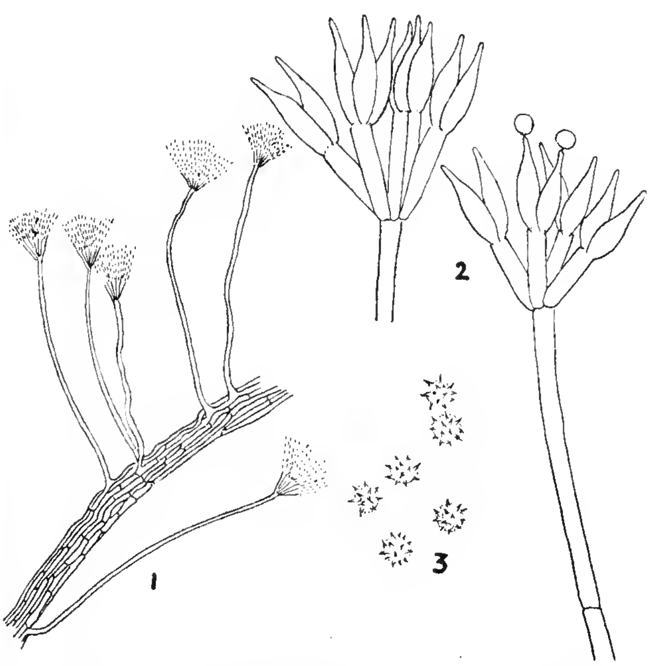

Fig. 38.—*P. verruculosum* Peyronel. 1. Rope and conidiophores, × 65. 2. Details of penicillus, × 600. 3. Spores, × 600.

The features of diagnostic significance are:

(1) The dark green sporing surface surrounded by a yellow rim.

(2) The funiculose growth.

(3) The globose and echinulate spores.

Isolated from the A and B horizons of the Frankston sandy podsol and from the litter of *Leucopogon virgatus*, as well as from the Mallee soil at a depth 70 in.

Penicillium funiculosum Thom. U.S. Dept. Agr. Bur. Anim. Ind. Bul., 118, 1910.

Malt. The colony diameter measures 4-5 cm. at 14 days. The surface is floccose. The colour of the sporing surface varies with different isolations; some are slate olive (XLVII) with mycelial overgrowth at the centre showing some pink colours, others have more yellow green tones such as grape green (XLI) with a yellow rim, others again show yellow mycelium through the colony. The surface may be zoned.

The reverse is in general cream with pinkish colours appearing and green sporing shades showing through.

Old malt slopes may show a deep red reverse.

Czapek. The colony diameter measures 3·5-4 cm. at 14 days. The surface is floccose, and again the colour varies. In some strains conidial formation is sparse and the colony shows pink shades; in others it is dark ivy green (XLVII) at the centre, but pink beyond. In others the green colour develops across the colony.

The reverse may be from deep ox-blood red to carmine (I) with the colour diffusing into the medium, to a much paler reverse, more purple red, with no colour in the medium.

Raulin. The rate of growth is similar to that on Czapek. The surface is floccose and is ivy green with pink and yellow shades right through the sporing area.

The reverse shows the same deep red shades as those on Czapek. The red colour may diffuse into the medium or not according to the strain cultured. In age all cultures become olivaceous-black (VLVI).

Morphology. Ropes of hyphae bearing conidiophores are present in the majority of the cultures but in some isolations they are not readily seen and the conidiophores then arise for the most part from trailing hyphae close to the substrate so that they are variable in length. They are smooth-walled and bear typical bi-verticillate and symmetrical penicilli. The metulae are 8-10 μ long and bear sterigmata characteristic of the section with the well-marked conidial tube. The spores are elliptic to sub-globose, 2·5 - 3 × 2 - 2·5 μ, smooth-walled, or sometimes appearing slightly roughened. Their connectives often persist on the spore coat and when fully mature the spores are almost chocolate brown and some still show connectives.

The features of diagnostic significance are:

(1) The dark green sporing colour often mixed with pink and yellow hyphae.

(2) The funiculose character of the surface.

(3) The elliptic to sub-globose smooth spores.

Isolated from the A and C horizons of the Frankston sandy podsol and from a mountain loam at Bogong High Plains, Victoria, at 0-9 in. and 10-32 in.

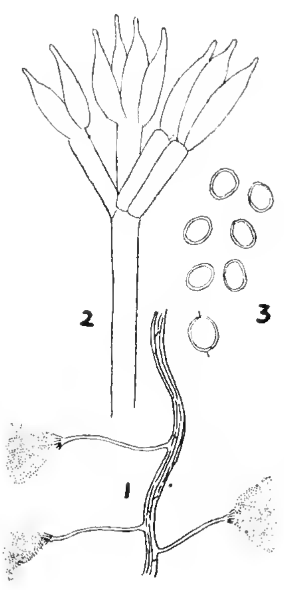

FIG. 39. — *P. funiculosum* Thom. 1. Habit sketch. 2. Details of penicillus, × 600. 3. Spores, × 600.

SCOPULARIOPSIS BREVICAULIS

Scopulariopsis brevicaulis (Sacc.) Bainier. Bul. Soc. Mycol., France, 23, 1907.

VARIETY A, represented by PVA_1

Malt. Colonies on malt agar spread fairly rapidly, their diameter in 14 days being 4·5-5 cm. or more. The colony appears thin when the plates are held up to the light; the surface is velvety to powdery, dark greyish olive to olive brown, deepening to clove brown or darker (XL), with a white margin.

The reverse shows the sporing colour through the rather thin growth in grey shades, light olive grey to olive grey (LI), with a broad white margin.

Czapek. The growth on this medium is so thin and sparse that it is necessary to hold the dish against the light to see it. The diameter measures 1·5-2 cm. in 14 days. There are no characters to record.

Raulin. The growth is again very thin, the rate of spread being comparable to that on Czapek. Sporing is so reduced that no colour develops for some time. Later, an olive brown powder may be visible.

The reverse remains colourless until the spores form, and then the spore colour is seen faintly through the growth.

Morphology described from growth on malt agar. The conidiophores arise either from trailing hyphae or from ropes of hyphae. They are smooth-walled and

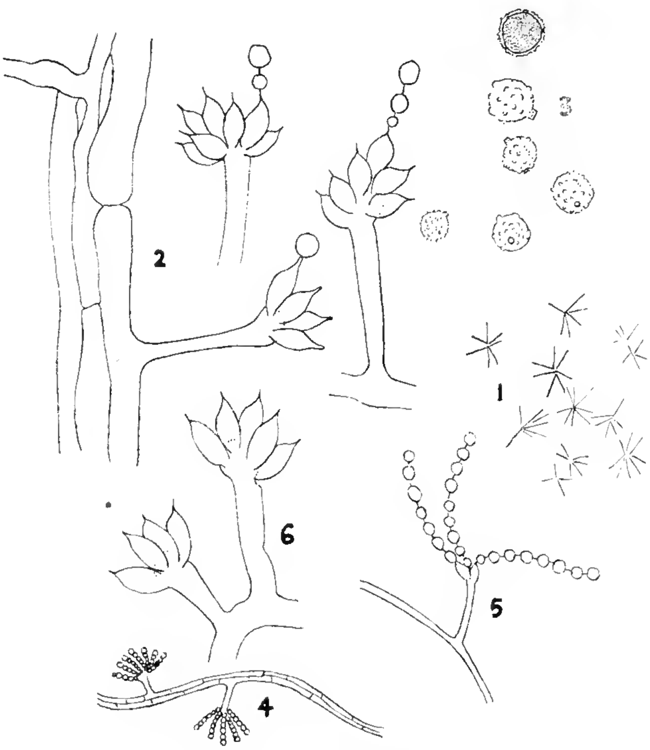

FIG. 40.—*Scopulariopsis brevicaulis* (Sacc.) Bainier.

Variety A. 1. Diagram of sporting heads. 2. Details of conidiophore, × 600. 3. Spores, × 600.

Variety B. 4. Diagram of rope with conidiophores. 5. Conidiophore from Czapek agar, × 65. 6. Details of conidiophore, × 600.

short; the average length is between 20 and 25 μ. Each is swollen at its tip, and over this surface are borne whorls, of from six to eight or more, short and broad sterigmata (5 μ × 2-2·5 μ). The spore chains are short, and form almost star-like groups when viewed from above under low magnification. The spores are roughly

spherical and the size appears to be variable; when fully mature, they are 5 μ in diameter, smoke-coloured and rough-walled, the roughening being in the form of coarse tuberculate prominences. The connectives are prominent in the spore chains, and when the spore falls away there is left a small spherical area on one end of it, rather suggestive of a germ pore; sometimes the connective itself remains attached to the mature spore and forms a plug over this area.

The features of diagnostic significance are:

(1) The very poor and transparent growth on Czapek agar.

(2) The dark brown colour of the spores.

(3) The prominent connectives which may remain attached to the spore at maturity, or the point of attachment may remain as a circular area resembling a germ spore.

Isolated from the A horizon (0-2 in.) of a greyish-brown silty loam at Pretty Valley, Bogong High Plains, Victoria.

VARIETY B, description drawn from isolation 257/6.

Malt. The colony diameter measures 4·5-5 cm. at 14 days. The growth is normal, not thin and transparent; the surface is floccose, deep to dark olive grey (LI), becoming olivaceous black (XLVI); sometimes colourless exudate drops may be present. The margin is white.

The reverse shows pale shades of grey.

Czapek. The colony at 14 days is very thin and transparent, and can only be seen by holding the dishes up to the light. The diameter measures 3-3·5 cm. in 14 days. The surface is very sparsely powdered with brown where spores are forming, otherwise there are no characters to record.

Raulin. The growth rate is comparable with that on Czapek, but the type of growth is more normal. The surface is floccose, light to dark olive grey (LI), with a broad white margin.

The reverse has a general cream background with buff colours at the centre.

Morphology. Similar to that of Variety A.

Raper and Thom, in their discussion of the *Scopulariopsis* group, divide the various strains examined by them into nine sections. Our isolation 257/6 seems to fit into their group 7. It differs from PVA_1 in its very different type of growth on malt agar and the darker sporing surface.

Isolated from the A horizon of the Frankston sandy podsol.

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4

THE WEDDERBURN METEORITIC IRON

By A. B. Edwards, D.Sc., Ph.D., D.I.C.

[Read 11 October 1951]

Introduction

The examination of the Wedderburn meteorite was undertaken as part of the research programme of the Mineragraphic Section of the Commonwealth Scientific and Industrial Research Organization, by whose permission it is published. The meteorite is specimen Reg. No. 11893, Geological Museum, Mines Department, Victoria. It was found by Mr. C. Bell, of Rushworth, when prospecting at a point three miles north-east of Wedderburn. He kicked it on the side of the road, noticed that it was very heavy, and thought it might contain gold—which, incidentally, it does. It appeared to be a complete meteorite, with well rounded surfaces, and shows a characteristic 'thumb mark'. It weighed 210 gm. and its overall size was 5 cm. × 3·6 cm. × 2·6 cm.

Chemical Composition

Chemical analysis of the Wedderburn meteorite reveals that it is an iron meteorite, containing about 24 per cent of nickel (plus cobalt). It thus has the distinction of being the most nickel-rich meteoritic iron yet found in Australia. Iron with 30, 35 and even 62 per cent nickel have been found in Brazil, and in the United States (Perry, 1944). Table 1 shows the composition of the Wedderburn iron, compared with other nickel-rich irons found in Australia.

TABLE 1

Chemical Composition of the Wedderburn and other Australian Meteoritic Irons

	1.	2.	3.	4.
Fe	74·35	82·29	85·31	85·66
Ni	23·95	16·90	13·18	13·56
Co	0·50	1·09	1·04	0·77
S	0·16	abs.	0·01	tr.
P	0·78	abs.	0·22	0·05
C	0·03	0·03	0·02	tr.
	99·77	100·31	99·81	100·04
Sp.Gr.	8·025	8·00	7·805	7·967

1. Wedderburn (*Analyst*: G. C. Carlos, Mineragraphic Section, C.S.I.R.O.).
2. Tawallah Valley, Roper River District (Hodge-Smith and Edwards, 1941).
3. Cowra, N.S.W. (Mingaye, 1904).
4. Mount Magnet, W.A. (Simpson, 1927).

The specific gravity of the main portion of the meteorite (159 gm.), which has been preserved, is 8·025, and it is probable that the specific gravity of the fresh iron is a little higher than this. The effect of surface weathering on the density was established on a sawn-off fragment with a rust-coated surface. With

its rust coating untouched the fragment had a specific gravity of 7·784. After grinding away much of the coating the density increased to 7·899, and after a further grinding, to 7·94. Some rusted α-iron was still present.

Microtexture

In the unetched polished section numerous irregular bodies of creamy-brown iron-nickel phosphide, and less numerous small bodies of darker brown troilite (FeS) can be distinguished dispersed through the iron; and it can be seen that the iron-nickel phosphide bodies are generally rimmed by a narrow zone of iron that is softer than the iron as a whole. Several of the troilite bodies show an intimate micro-intergrowth with iron, and one or two are associated with a little carbonaceous matter. Grains of gold were observed, associated with the phosphide in one section.

A light etching with 2% nitric acid in alcohol, or with 20% aqueous ferric chloride, brings out an incipient Widmannstätten texture (Pl. II, figs. 1 and 2), comparable with that found in other nickel-rich irons, such as the Tawallah Valley iron (Hodge-Smith and Edwards, 1941). The etching reveals that the iron-nickel phosphide bodies, which are up to 0·05 mm. $\times$ 0·05 mm., are distributed more or less uniformly through the iron, and variously oriented, with a tendency to lie parallel to the octahedral planes of the iron, and that they are commonly enclosed by narrow rims of α-iron, up to 0·05 mm. thick (Pl. II, fig. 1). Occasional phosphide bodies have no such rim, others have the rim on one side only. The apparent width of the α-iron rim varies with the orientation of the phosphide bodies and their rims relative to the plane of the polished section. Occasionally the plane of the section lies wholly in a rim of α-iron (Pl. II, fig. 1).

In the interspaces between the phosphide bodies are areas which with light etching appear to be predominantly γ-iron carrying clusters of minute lens-like bodies of α-iron, the α-iron bodies being oriented parallel to the octahedral planes of γ-iron (Pl. II, figs. 1 and 2). Close inspection of the clear matrix between the α-iron bodies show that it is finely mottled, and with more severe etching, it darkens. Very high magnification reveals that it is an extremely fine-grained intergrowth of bodies of α-iron that grade down to sub-microscopic sizes, in a γ-iron matrix, the α-iron bodies being oriented like the visible α-iron bodies shown in Pl. II, figs. 1 and 2), forming a so-called 'plessite' intergrowth.

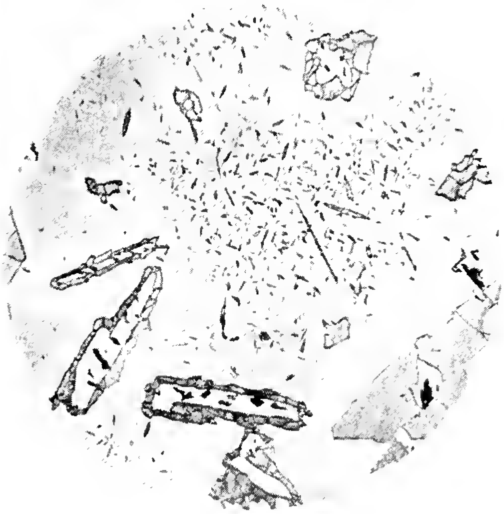
The γ-iron adjacent to the phosphide bodies and the coarser oriented α-iron bodies has been 'drained' free of α-iron by solid diffusion, and segregation to the larger areas of α-iron. This feature is more apparent with stronger etching, which leaves the 'drained' areas unetched, while the sub-microscopic intergrowths of α-iron and γ-iron appear black at all but high magnifications.

The marginal 2 to 3 mm. of the meteorite remains practically unetched by weak nitric acid, because here rapid chilling has prevented any fine precipitation of α-iron bodies, and all the matrix iron is in the γ-form, with a nickel content comparable with the overall nickel content of the iron.

The α-iron and γ-iron are readily distinguished by their etching behaviour:

α-iron: positive—HNO_3, $FeCl_3$, $HgCl_2$.
negative—HCl(?), KOH, KCN.
γ-iron: negative—HNO_3, HCl, KOH, KCN, $FeCl_3$, $HgCl_2$.

The α-iron, moreover, rusts readily on exposure in the polished surface, whereas the γ-iron does not (Pl. II, fig. 3).



1

2

3

4

Fig. 1.—Wedderburn iron, lightly etched with 2% nitric acid in alcohol. The hard white bodies are schreibersite, rimmed with α-iron, and the oriented small dark bodies within them are α-iron. The matrix is a fine intergrowth of α-iron and γ-iron, except in the vicinity of the large bodies of α-iron, where it consists only of γ-iron. $\times$ 150.

Fig. 2.—Part of the field of view of Fig. 1, magnified, showing the duplex nature of the matrix. $\times$ 450

Fig. 3.—Differential rusting of α-iron (dark). The relatively homogeneous area is on the edge of the structureless marginal portion of the iron. $\times$ 75.

Fig. 4.—Area of gold (light grey) in unetched iron (medium grey), at the edge of the specimen. Dark areas are pits. $\times$ 500.

Iron-nickel Phosphide

Only one iron-nickel phosphide is present. It is creamy-brown, too hard to scratch with a steel needle, and brittle, so that it is difficult to polish, and tends to pluck out between fractures. It is weakly anisotropic, and is resistant to all etching reagents, other than HCl, which causes slow effervescence. In these respects it parallels the iron-nickel phosphide described as schreibersite B from the Packenham and Cranbourne meteorites (Edwards and Baker, 1942, 1944). The phosphide bodies range in size from ·1 × ·1 mm. up to ·50 × ·05 mm. and tend to a stumpy and irregular prismatic form.

Troilite

Associated with the schreibersite bodies are several small, more or less ovoid, bodies of iron sulphide. It is darker brown than the schreibersite, and rather difficult to polish on account of its fine granular texture, which is made apparent by its strong anisotropy. It effervesces with 1 : 1 nitric acid, which distinguishes it from pyrrhotite. Some areas show a fine intergrowth of troilite with metallic iron, as in a eutectic, but most are massive. Very occasionally the troilite is associated with a carbonaceous matter.

Carbonaceous Matters

The grey carbonaceous matter associated with troilite appears isótropic, and lacks the strong anisotropism and pleochroism of graphite. The areas of it are too small to be determined with certainty, but the association with the pyrrhotite is similar to the association of graphite with pyrrhotite in other meteoritic irons, and the suggestion is that it is the form of carbon termed cliftonite that has been found in some irons.

Gold

Two areas of bright yellow gold were observed in one section. The larger area when first observed measured ·25 × ·20 mm., but on re-polishing the surface in an attempt to improve the polish was reduced to two areas, one ·05 × ·03 mm. and one ·12 × ·05 (Pl. II, fig. 4). Unfortunately the gold area was intersected by the saw cuts made to obtain a fragment for analysis, and its situation on the deeply scored edge of the piece polished, and adjacent to a shattered body of schreibersite, made it impossible to obtain a good polish. The rapid reduction in size of the gold areas on re-polishing suggested that it occurs as a thin film-like area, and that further polishing might destroy it completely.

The second area of gold was a thread about ·01 × ·005 mm., in the interstices of a schreibersite area.

Etching tests revealed that the gold was inert to 1 : 1 nitric acid, and rapidly etched by potassium cyanide. This, combined with the fact that it was much brighter than the enclosing iron, left no doubt of its identity.

In view of the capacity of gold to alloy with iron, it is somewhat surprising that the gold should occur in such distinct form. It is most unlikely that the gold could have entered from some extraneous source.

Gold has been detected in other Australian meteorites. Liversidge (1902) recorded it in the Bugaldi and Gilgoin No. 1 meteorites, and in the Nurraburra iron (Liversidge, 1903), and Mingaye (1904) observed it in the Mount Dyrring meteorite. Geochemical investigations have established that gold is one thousand-fold more abundant in nickel-iron meteorites than in the earth's crust. The average

gold content of the earth's crust is estimated as ·005 grams per ton, whereas the average content of nickel-iron meteorites is 5 grams per ton (Goldschmidt, 1937).

Origin of the Microtexture

The Widmannstätten textures in metoritic irons arise from the transformation of original γ-nickel iron to α-nickel iron (Derge and Kommell, 1937; Hodge-Smith and Edwards, 1941; Perry, 1944). The transformation proceeds according to equilibrium relationships as outlined by Marsh (1938). The newly precipitated α-iron (kamacite) grows most readily in the octahedral planes of the γ-iron, so that oriented blade-like crystals of α-iron develop.

In artificial irons with more than 20% nickel the transformation temperature is so depressed that generally no transformation to the α-state occurs. Prolonged annealing of artificial alloys of this composition fails to produce any transformation (March, 1938), but, possibly owing to the effect of minor impurities, Derge and Kommell (1937) obtained a fine Widmannstätten texture in an alloy with 27% nickel, by allowing it to cool from 1400° C. to room temperature in about twelve hours.

The Wedderburn iron, with 23·23% nickel (and cobalt), might have been expected to be structureless, i.e. a nickel-rich ataxite. Its texture, however, is that of an 'eotaxite' and resembles that of the Tawallah Valley meteorite which contains a total of 18 per cent (Ni + Co), but is finer grained. Its crystallization behaviour has paralleled that of Derge and Kommell's alloy, although in view of the small size of the Wedderburn iron, it must have cooled more rapidly. Presumably impurities such as phosphorus or the presence of the schreibersite bodies, which served as nuclei about which much of the α-iron formed, or accumulated, stimulated the transformation.

Textures of this type persist in meteoric irons until the (Ni + Co) content is in excess of about 35 per cent. The San Cristobal and Limestone Creek (Alabama) irons with 26·6 and 31·47 per cent (Ni, Co) respectively show such textures, whereas the Santa Catherina (Brazil) iron with 35·87 per cent (Ni, Co) and the Octibbeha (Mississippi) iron with 62·73 per cent (Ni, Co) are true ataxites (Perry, 1944, p. 68).

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5

THE GEOLOGY OF THE COASTLINE OF WARATAH BAY BETWEEN WALKERVILLE AND CAPE LIPTRAP

By A. W. Lindner, B.Sc.

[Read 11 October 1951]

Abstract

A study of nine miles of the Waratah Bay coastline has been made, and a larger area, the Cape Liptrap peninsula, is referred to in a discussion of the structural geology and geomorphology.

Four sedimentary and two igneous formations have been mapped. Examination of fossils has established that Tremadocian (Lower Ordovician) sheared calcareous shales and siliceous limestones, and Devonian limestones, sandstones and shales are present. A group of altered basic lavas, basic intrusive rocks, pyroclastics and sediments, referred to as diabase, is probably equivalent to the Heathcotian rocks.

The Palaeozoic formations are separated by faults, gabbro being intruded along the fault between the diabase and the Tremadocian sediments. The relation of the gabbro to the Devonian is not known. The Devonian sandstones and shales have been more severely folded than the other Palaeozoic rocks and are believed to occupy a synclinal area between the structural axes of the diabase and the Tremadocian to the east, and Upper Ordovician to the west.

A mantle of Tertiary sands and conglomerates covers the older rocks, this being regarded as a marine platform which was raised during the late Tertiary uplift of South Gippsland to form a coastal plain. The coastal plain is in a youthful stage.

Structure and texture of the rocks have played an important role in the present configuration of the coastline. Erosional processes along the shore are discussed.

Introduction

Waratah Bay is the stretch of water between Cape Liptrap and Wilson's Promontory, South Gippsland, Victoria. The area surveyed is a nine-mile strip of the western coastline of Waratah Bay south from the township of Walkerville to Cape Liptrap. For discussion of the structure and geomorphology reference is made to the Cape Liptrap peninsula (Fig. 1).

The Cape Liptrap peninsula is an undulating plateau, about 30 square miles in area, with a low but dominant ridge forming a local divide striking approximately S 30° W from Rock Hill (530 feet) to Cape Liptrap, which is approximately 300 feet above sea level (Fig. 1). A number of small creeks drain into the sea on each side of the ridge. Morgan's, Middle and Ten Mile Creeks are the largest on the western side. Outcrops are rare because of the extensive layer of Tertiary gravels and sands and recent wind-blown sand mixed with plant humus.

The coastline is rock and, except for Maitland beach, is bounded by cliffs up to 100 feet high. The headlands rise abruptly from wave-cut platforms and the cliffs at Cape Liptrap are about 250 feet high. Digger Island, about 80 yards across and 250 yards in circumference, is a tied island at half tide. Rock stacks occur off the headlands of limestone and most of the these are connected to the mainland at low tide.

Walkerville may be reached by road or rail (to Fish Creek) from Melbourne. By road the distance is 103 miles via Leongatha and Fish Creek or 110 miles via Leongatha and Tarwin. Fish Creek railway station is 100 miles from Melbourne and the road from Fish Creek to Walkerville is 16 miles. This road is in bad condition during wet weather.

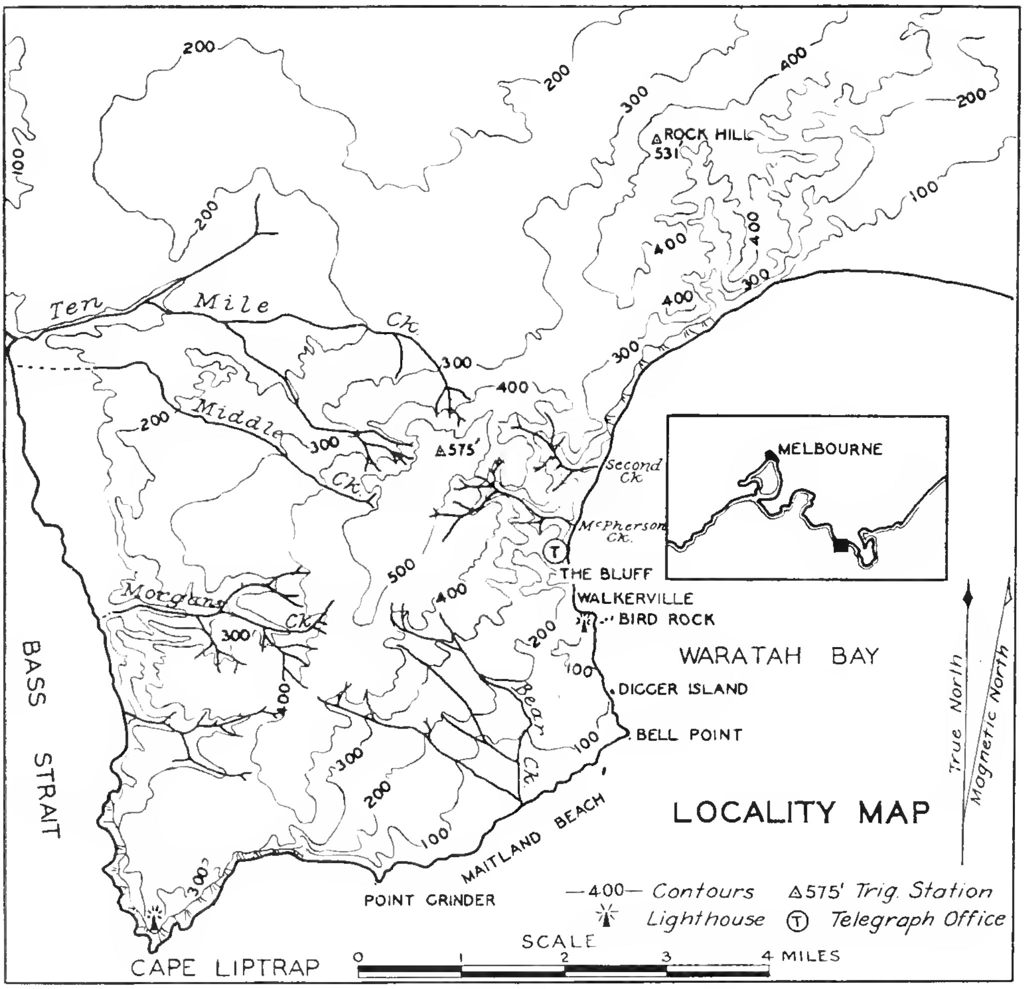

Fig. 1.

Field work extended over four short periods between 1945 and 1950. In February, 1948, a continuous compass and pace traverse was made along the shore from The Bluff to Point Grinder, together with two short chain and compass traverses in the vicinity of Bell Point. No traverses with linear control have been made between Point Grinder and Cape Liptrap. As most of the outcrops are exposed on the foreshore, field work was planned to coincide with low tides.

The locality map (Fig. 1) is based on the 1 mile = 1 inch military survey sheets of Waratah and Yanakie. The detailed inset (Fig. 2) and the areal geological

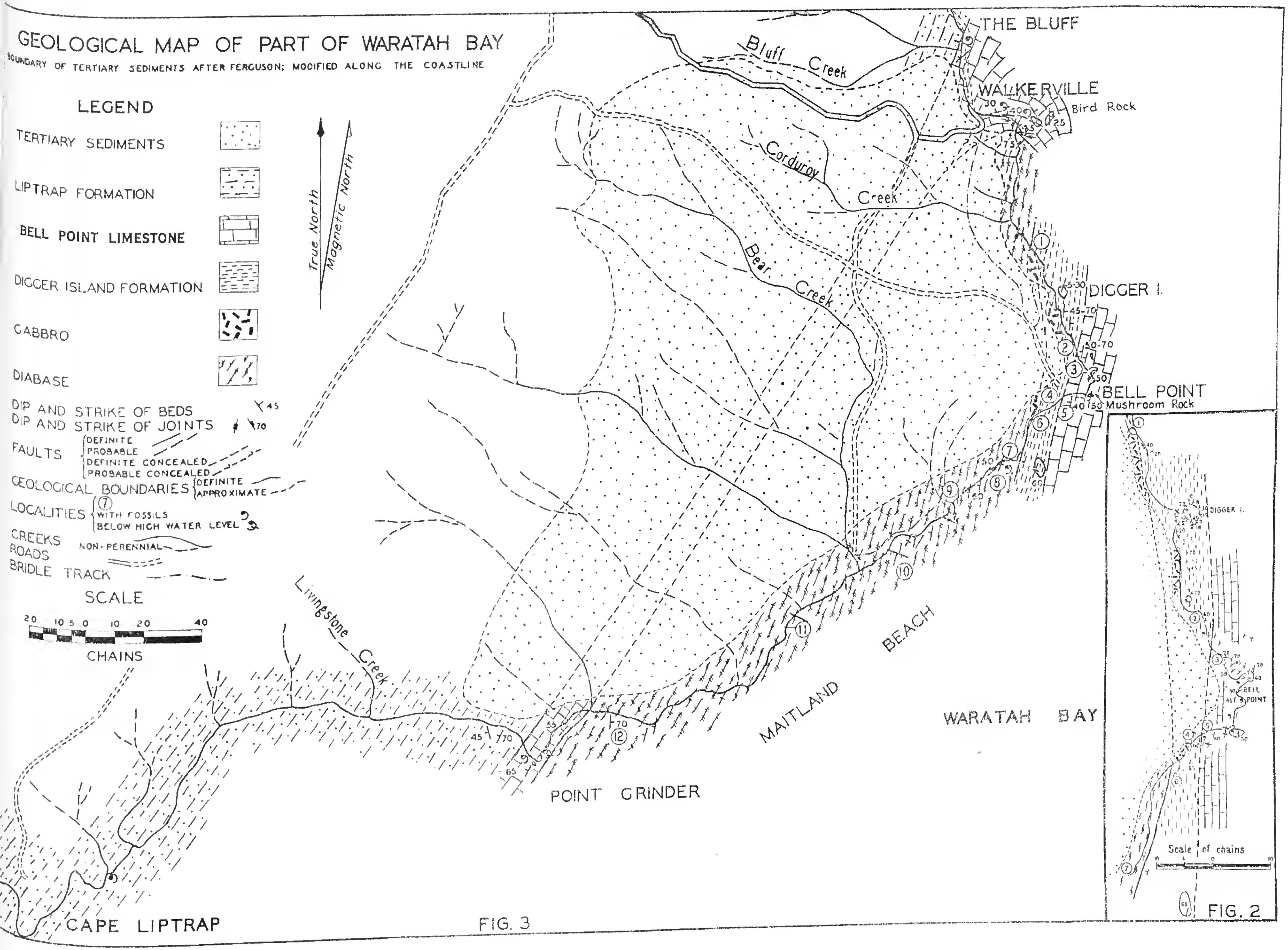
GEOLOGICAL MAP OF PART OF WARATAH BAY
BOUNDARY OF TERTIARY SEDIMENTS AFTER FERGUSON; MODIFIED ALONG THE COASTLINE
LEGEND
TERTIARY SEDIMENTS
LIPTRAP FORMATION
BELL POINT LIMESTONE
DIGGER ISLAND FORMATION
GABBRO
DIABASE
DIP AND STRIKE OF BEDS
DIP AND STRIKE OF JOINTS
FAULTS
DEFINITE
PROBABLE
DEFINITE CONCEALED
PROBABLE CONCEALED
GEOLOGICAL BOUNDARIES
DEFINITE
APPROXIMATE
LOCALITIES
WITH FOSSILS
BELOW HIGH WATER LEVEL
CREEKS
NON-PERENNIAL
ROADS
BRIDLE TRACK
SCALE
20 10 5 0 10 20 40
CHAINS
True North
Magnetic North
THE BLUFF
Bluff Creek
WALKERVILLE
Bird Rock
Corduroy Creek
Bear Creek
DIGGER I.
BELL POINT
Mushroom Rock
Livingstone Creek
MAITLAND BEACH
WARATAH BAY
POINT GRINDER
CAPE LIPTRAP
DIGGER I.
BELL POINT
Scale of chains
FIG. 3

FIG. 2

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map (Fig. 3) have been constructed from traverse data and the military, parish and geological plans of Waratah.

Previous field work in the area was done by officers of the Geological Survey of Victoria. Murray (1876), during a survey of South Gippsland, was the first geologist to visit the area. He reported on the occurrence of limestone at Point Grinder and Bird Rock, and brought back samples of limestone and diabase for analysis, and a collection of corals. Ulrich mentioned fossils in the Progress Report for 1875 and suggested an Upper Silurian or Lower Devonian age for the limestone. A description of the gabbro appeared in the Progress Report of the Survey in 1877 and in the same report McCoy recorded the presence of *Palaeopora* (= *Heliolites*) *interstincta* (Wahl). In 1894, Stirling investigated the deposits of silver in the contact zone of the gabbro with the Tremadocian sediments. However, the silver is not present in payable quantities. Stirling also mentioned that the Tertiary sediments near the coast had been sluiced for gold.

In 1898, Etheridge Jnr. reported on a collection of corals from Waratah Bay and named a new species, *Tryplasma murrayi*. Crinoidal limestone, a dorsal valve of a spiriferid and indeterminable plant remains are also recorded. Etheridge regarded the age as Upper Silurian. In 1904, Hall identified an imperfect specimen of *Diplograptus* from Bald Hill, eight miles north-north-west of Walkerville, and an Upper Ordovician age was established for outcrops near Ten Mile Creek and Bald Hill.

Osmiridium, in the beach sands, was recorded in 1914. Kitson, in 1917, observed that sediments at Waratah Bay contained a similar suite of fossils and were lithologically similar to the Mt. Ida beds in the Heathcote District. Lignitic material was discovered near Digger Island in 1925, when Baragwanath examined an alleged deposit of bitumen at that locality. Ferguson completed the first geological survey of the Liptrap Peninsula and his geological map was published in 1928 in the Parish Series of the Geological Survey of Victoria. A complete list of references to Waratah Bay is included in the bibliography.

Stratigraphy

Nomenclature

Four sedimentary and two igneous formations have been recognized in the area. A detailed study of trilobites collected from the sediments at Digger Island has been made by Dr. O. P. Singleton (manuscript) and he has established a Tremadocian age for these sediments. The faunal assemblage is new for Australia and the sedimentary succession has been called the Digger Island Formation. Fossil material collected from other sedimentary rocks allows only general indications of the age of the sedimentary formations to be made. Two formations of Devonian age have been named, the Bell Point Limestone and Liptrap Formation, as there are distinct lithological variations from rocks of similar age elsewhere in Victoria. Correlation with other sections in Victoria cannot be attempted without more palaeontological and stratigraphical evidence and therefore the following formation names are suggested: Digger Island Formation, Bell Point Limestone, and Liptrap Formation.

The conglomerate and sands which overlie the Palaeozoic rocks are probably of Tertiary age but have not been specifically named. The term 'diabase' is applied in the sense that it is used in Victoria to describe collectively a complex series of

altered basic and intermediate lavas with interbedded pyroclastics, ash beds and sediments of pre-Upper Cambrian age. Lithology and regional structure of the diabase is the only evidence to correlate the group with the Heathcotian formation of the Mt. William-Heathcote-Colbinabbin belt or the Mt. Wellington and Howqua areas.

Gabbro is retained as a name for the basic intrusive rock, although several basic rock types appear to have been present originally. However, the rock has been serpentinized and no outcrops of the primary rock types are known.

Sedimentary Rocks

Digger Island Formation

Definition. The Digger Island Formation is a sequence of fossiliferous, yellow-brown, grey and grey-green shales and calcareous shales; poorly bedded, yellow decalcified mudstone and thin-bedded, fossiliferous, grey, grey-green and purple, fine-grained, dense, siliceous limestones. The sediments are strongly sheared and estimated to be 120 to 130 feet thick. They are well developed on Digger Island, which has been chosen as the type locality. On its western boundary the formation is either intruded by gabbro or faulted against the diabase; on its eastern boundary it is faulted against the Bell Point limestone.

Distribution. The formation extends from locality 1 southwards beyond Digger Island, passes to the west of Bell Point, where it is faulted against the Bell Point Limestone, and reappears in the cliff face at locality 4 as deeply weathered outcrops of yellow, sheared, nodular, calcitic mudstone. At locality 6 there is a contact with the gabbro, and from there to locality 7 the formation is faulted against the diabase. The black-stained, unfossiliferous limestone stack off locality 7 is made up of rocks belonging to this formation.

Lithology. Shale and mudstone with a varying carbonate content are the dominant rock types. The thin-bedded, siliceous limestone contains calcareous nodules. Sharp lateral changes from one rock type to another are common.

Along the shoreline north from Digger Island to locality 1 and south to locality 2 the formation has been contact metamorphosed by the gabbro, which recrystallized and reconstituted the sediments for 70 to 80 feet from the contact with complete loss of bedding, destruction of fossils and development of jointing. Beyond about 150 feet from the contact, the noticeable effect of metamorphism ceases, the bedding becomes apparent and jointing is less pronounced.

Thin sections, cut from specimens taken within 40 feet of the contact with the gabbro near locality 1, indicate the variable composition of the sediments of the Digger Island Formation. Under the microscope, one section is seen to contain angular quartz grains up to 0·3 mm. in diameter. Plagioclase is also present. The rock has a fine-grained, banded matrix of a carbonate mineral and clay minerals. Other sections contain a high proportion of fibrous brucite associated with clusters of granular vesuvianite up to 1 mm. in diameter. A carbonate mineral occurs as subhedral crystals usually less than 0·1 mm. in diameter in the matrix. Euhedral pyrite, about 0·1 mm. in size, is common in all sections. Although qualitative acid tests failed to indicate the presence of dolomite or magnesite in the various types of unmetamorphosed sediments, magnesium is evidently present in places. The presence of a carbonate mineral and quartz in a thermally metamorphosed rock indicates that the intrusion of the gabbro was accompanied by a very low grade thermal metamorphism.

Palaeontology. A faunal assemblage of trilobites and brachiopods, peculiar in Australia, was found by Mr. P. W. Crohn and the writer. Brachiopods occur near locality 2 on the mainland (Fig. 2), on the south and east sides of Digger Island, and are associated with trilobites at about high water level on the south-west and west sides of the island. Trilobites are known from several localities on the north and west sides of Digger Island and below high water level on the west side of the island. Trilobite fragments occur at locality 4.

Although the fossils are sheared they are well preserved. The trilobites are as follows:

Geragnostus laterhachis sp. nov. Singleton m.s.
Geragnostus laterhachis forma *obsoleta* nov. Singleton m.s.
Kainella occidentalis sp. nov. Singleton m.s.
Leiostegium elongatum sp. nov. Singleton m.s.
Hystricurus sulcatus sp. nov. Singleton m.s.
Onchonotus rectifrons sp. nov. Singleton m.s.
Archaeharpes mirabilis gen. et sp. nov. Singleton m.s.
Protopliomerops quadrispinosus sp. nov. Singleton m.s.
Phumaccphalus insuetus gen. et sp. nov. Singleton m.s.
Gen. et sp. nov. undetermined.
Trilobite indet.
Pygidium unidentified.

Dr. Öpik has undertaken the examination of the brachiopods. Cystid plates are also present (Singleton, personal communication).

Dr. Singleton has stated (person communication) that the presence of the *Kainella-Leiostegium* association in the trilobite fauna of the Digger Island Formation indicates an early Tremadocian age for these beds. The general easterly dip of the sediments on Digger Island indicates that the trilobite beds are stratigraphically lower than those bearing brachiopods. Jointing and frequent small-scale faulting make it impossible to trace the beds laterally with any certainty and the relationship of the fossils on the mainland to those of Digger Island is not known.

Dr. Öpik (personal communication) has suggested lithologic affinities of the formation with a part of the Caroline Creek shales and sandstones of Tasmania (Lewis, 1940).

Bell Point Limestone

Definition. This formation consists of well bedded, fossiliferous, grey, silty limestone; bedded to massive, grey-white limestone, partly recrystallized and not richly fossiliferous, with local development of bioherms; fossiliferous, brown, silty limestone with angular chert fragments and fine micaceous mudstone. At Bell Point, the type locality, the formation is terminated on the west by a fault separating it from the Digger Island Formation and the base of the section forms the coastline on the east. At Point Grinder, and between Bird Rock and The Bluff, the formation is faulted against the Liptrap Formation on the west and against the diabase on the east; 350 feet of sediments have been measured, but the total thickness of the formation is greater than this.

Lithology. The grey, silty limestone is a dense, fine-grained, dark-coloured rock, commonly veined by calcite. The beds range from two to nine inches in thickness and are, in places, massive. These are interbedded with an evenly bedded light grey limestone, with beds ranging from six to twelve inches in thickness.

Thickness of the grey limestones is estimated to be at least 140 feet. The limestone was quarried and calcined at The Bluff for many years.

A large crudely bedded mass of grey-white limestone (about 100 × 100 × 30 feet), between the north arm of Bell Point and Mushroom Rock, is regarded as a bioherm. Beds lateral to the top of the bioherm contain angular fragmental limestone. Elsewhere, the grey-white limestone is poorly bedded or massive. It is a dense, medium-grained, clastic, pure crystalline rock and is oolitic on the inner stack at Bird Rock. One hundred and forty feet of this limestone is exposed at Bell Point and 420 feet at Point Grinder.

Angular chert fragments up to 12 mm. in diameter are embedded in the fossiliferous, brown, silty limestone and massive brown mudstone. Beds of similar lithology to the grey silty limestone, but containing agglomerate with unsorted, angular, cherty material for the lower six feet, occur at Point Grinder.

Distribution. Outcrops of the formation occur at Bell Point, Point Grinder, and between Bird Rock and The Bluff. The grey-white limestone overlies beds of grey limestone containing agglomerate at Point Grinder, but forms the lowest part of the exposed section at Mushroom Rock. The three stacks at Bird Rock consist of grey-white limestone. These stacks are isolated from the outcrops of brown limestone to the west near Walkerville, although the strike of the brown limestone indicates that these beds underlie the grey-white limestone. At Bell Point, the grey limestone, in an abrupt facies change, conformably overlies the grey-white limestone at Mushroom Rock. Grey limestone and mudstone also occur between Walkerville and The Bluff, and micaceous mudstone is exposed in the road cutting at Walkerville. The outcrops between Bird Rock and The Bluff are not continuous and the break in the section may be due to the presence of more easily eroded sediments and also to the major changes of strike which occur in this locality.

Palaeontology. Fossils are known from the grey-white limestone at Point Grinder, Mushroom Rock and the bioherm to the north, and at the middle stack at Bird Rock. Stromatoporoids and crinoid fragments are common to all localities. A gastropod and cephalopod are known from Mushroom Rock. Corals occur at the Bird Rock locality and at Point Grinder. *Favosites nitida* Chapman has been identified by Dr. Hill from Point Grinder.

The change of conditions which resulted in the deposition of the grey limestone favoured an entirely different assemblage of forms. Some beds are richly fossiliferous. A trochoform gastropod is the only fossil in the lowest 75 feet. Above this, Spiriferid brachiopods occur together with the gastropod. There follows a section of unfossiliferous rocks, above which the beds contain rugose and rare tabulate corals, Spiriferids and other brachiopods and several small species of gastropods, including turreted and turbinate forms. A grey silty limestone bed, faulted against the Digger Island Formation at locality 5, contains *Conocardium* and ostracods. Beds rich in corals alternate with beds rich in brachiopods to the top of the section, although both forms are present in any given bed.

Tabulate and rugose corals, which macroscopically appear to be similar to the corals of the grey limestone at Bell Point, occur in the brown limestone west of Bird Rock. *Amphipora* occurs in the grey silty limestone near The Bluff.

From field evidence, the sequence of rocks in the formation is a basal, brown, silty limestone and mudstone with chert pebbles overlain by grey-white limestone. Above this is grey silty limestone.

Liptrap Formation

Distribution. This formation continues westward beyond Cape Liptrap from its faulted contact with the Bell Point Limestone, west of Point Grinder. Its extent northwards along the coastline from The Bluff, where it is faulted against the Bell Point Limestone, is unknown. The brief examination of the formation was restricted to the coastline between Point Grinder and Cape Liptrap and in the immediate vicinity of The Bluff.

Lithology. The sediments include light grey medium- to coarse-grained quartz sandstone with some bands of grit; dark grey medium- to fine-grained sandstone, interbedded with dark grey to smoky grey and black mudstone and slate, in places micaceous. The coarse sandstone is usually massive or thickly bedded and contains thin veins and stringers of quartz. The conglomeratic material in the coarse sandstone contains chert and green quartzite. The medium-grained sandstone and the mudstone are well bedded and often current-bedded with well developed top, fore and bottom sets. Both the fine-grained sandstone and the mudstone are commonly ripple-marked. The ripple-marks have a wave length of about 5 cm. and an amplitude of ·5 to 1 cm. Subaqueous penecontemporaneous slumping has occurred in some beds of the mudstone.

Palaeontology. Ferguson (1928) recorded fossil plants at Livingstone Creek and a breccia with corals on the Bass Strait coastline, north-west of Cape Liptrap. Solitary and compound corals were found by the writer at several localities along the two miles of coastline north-east from Cape Liptrap. The corals occur in medium- and coarse-grained sandstone and are commonly associated with the pebbles in the conglomeratic bands. Corals also occur occasionally in the slumped beds. The corals are similar to those found in the Sulcor Limestone of New South Wales, which is lower Middle Devonian (Hill, personal communication). However, the lithology and the relationship of the fossils to the coarse-grained sediments are similar to the description of the lithology of the Walhalla Beds in the Walhalla Synclinorium (David, 1950).

The stratigraphic relationship of the Bell Point Limestone and Liptrap Formation cannot be determined in the field, and although the faunal assemblages of both have a Devonian aspect, palaeontological evidence is insufficient at present to indicate their relative ages.

Tertiary Sediments

Distribution. Tertiary sediments overlie the Palaeozoic rocks on the cliff tops and for a considerable distance inland between Walkerville and Point Grinder. They also cap Digger Island. Small outcrops occur at low water level near the fault between the Digger Island Formation and Bell Point Limestone north of locality 3, although these outcrops may not be *in situ*. However, there is a deposit of lignitic material on the foreshore about 15 chains south of Digger Island.

Lithology. The sediments consist of a white, fine quartz-conglomerate and sands. The sediments are poorly bedded and are consolidated, but not well cemented. Rounded to sub-rounded pebbles of milky quartz and rare diabase, 2 to 10 mm. in diameter, are unevenly distributed in a fine sandy matrix. Woody fragments and stumps, partly replaced by pyrite, are common in the lignitic material south of Digger Island. Depending upon the movement of the sand on the beach, the deposit may be over a foot below the surface (as in January 1950), or lignitic

material may protrude through the surface of fine sand (as in February 1948). Under the latter conditions the shape of the deposit may be determined at low tide by the area ringed by water seepages. The deposit measures 90 feet by 60 feet.

The formation is 80 to 100 feet thick in places. However, the thickness is variable and there are two inliers of diabase on the coastal plain, north of Bear Creek.

Age of the sediments. The conglomerate is possibly a beach deposit, as it is much the same in grain size and composition as the present day beach gravels in the gaps in the diabase between locality 1 and Bird Rock, although the gravels are more rounded. The situation of the sands and conglomerate on a level platform close to the present day shoreline also suggest that the conglomerate is a beach deposit.

Uplift of 150 to 200 feet of the conglomerate to its present position was probably connected with the late Tertiary movements in South Gippsland (Hills, 1934), and a Tertiary rather than Quaternary age for the conglomerate is indicated.

Igneous Rocks

Diabase

Included under this title is a group of rocks, most of which were originally basic lavas with associated interbedded tuffs and agglomerates. It is possible that medium-grained igneous rocks were intrusive into the group. Interbedded sediments are rare. Some metasomatism has resulted in the formation of chert and jasperoid rocks.

Extrusive rocks. The rocks are dark, green-grey, dense, fine-grained, even-textured, and weather to a yellow clay soil. Minerals grains are rarely distinguishable and are not identifiable macroscopically. At most localities, deep etching of the surface through weathering, a well developed but irregular joint pattern, and shearing have obliterated the structure and texture of the rocks. Therefore the individual lava flows are difficult to distinguish, except where they are in contact with tuffs. However, near locality 11, silicification over a thickness of several feet has occurred in the diabase and in this zone the original structure of ropy lava flows, several inches to a foot thick, is still visible. Structures strongly resembling pillow lavas occur on the foreshore near locality 11 and also in the cliff face between localities 8 and 9.

Under the microscope, the lava is seen to be typically a fine-grained equigranular rock, composed of granular augite, lath-like, subhedral felspars and interstitial serpentine minerals. Usually the augite crystals are less than 0·2 mm. in diameter and commonly occur in granular clusters. The felspar laths are 0·2 to 0·3 mm. in length, although some sections contain rare, porphyritic, tabular felspar crystals up to 1 mm. in length. The felspar usually is cloudy and kaolinized. Where it can be identified it is andesine, approaching labradorite. A slightly pleochroic serpentine mineral occurs as poorly defined pseudomorphs after olivine, and also as an interstitial and vein mineral. Magnetite is associated with the serpentine. There is usually a little calcite, felspar and quartz present in the joint planes. Pyrite and leucoxene occur in some sections.

The rocks show little sign of the low-grade dynamic metamorphism which is characteristic for the Heathcote (Skeats, 1908; Singleton, 1949) and Howqua areas (Teale, 1919). However, in some sections veins of lawsonite indicate that metamorphism has occurred.

Pyroclastic rocks. Tuffs are recognizable in the field as stratified and banded rocks, commonly containing pebbles which originally were the constituents of a volcanic breccia. The tuffs are usually red-brown, green-grey or grey in colour. Tuff beds occur in the outcrops of diabase along Maitland Beach and are usually 20 to 40 feet thick. The greatest thickness observed was 80 feet. About half a mile south of locality 11, a tuff bed, 50 feet thick, is associated with thin red tuff beds which are alternately bedded with igneous rocks for 100 feet.

Although the bedding of the tuffs has been entirely obliterated in some places—for instance no stratified rocks are seen in the diabase between Bird Rock and locality 1—thin sections from outcrops near the gabbro intrusion near locality 1, and from the diabase immediately adjoining the fault boundary at locality 12, indicate that these massive, macroscopically structureless rock types were tuffs.

Thin sections of the tuffs commonly consist of kaolinized felspar, quartz and calcite; ferro-magnesian minerals are notably absent. In the groundmass, the quartz is in most cases microcrystalline and may occur in aggregates of almost pure silica up to 1 mm. in size, but is usually mixed with and subordinate to completely kaolinized, minute felspar laths. Microcrystalline calcite occurs in the groundmass of some specimens. Calcite up to 0·5 mm. in size also occurs as a vein mineral, associated with quartz up to 1 mm. in size, showing strain extinction. The tuff at locality 12 consists of microcrystalline clay mineral with crystals elongated and oriented in two directions at about 60 degrees.

A large outcrop of a light-brown rock in the diabase near locality 1 appears in thin section, to resemble the siliceous-carbonate rocks described from other areas of diabase in Victoria. Microscopically, the rock is similar in composition to the other tuffs, but contains a much higher proportion of calcite in the groundmass. Veins of calcite are also more common.

Intrusive rocks. Narrow belts, suggesting dykes, occur in the diabase between Bird Rock and locality 1. The rocks are macrocrystalline and appear to be dolerite.

Metasomatism. Localized veins and pockets of jasper occur along joints and fractures and in places large irregular masses have undergone partial replacement by silica with introduction of iron oxide.

A black chert near locality 12 consists of microcrystalline quartz associated with pyrite in veins, in a dark, siliceous matrix. The rock has not been completely silicified and stratification indicates that it was originally either a tuff or a sediment.

The siliceous-carbonate rocks associated with the diabase are regarded as tuffs which have been subjected first to carbonating solutions and subsequently to silica-rich solutions, resulting in cherty patches in a carbonate rock (Skeats, 1908).

Sediments. Outcrops of shale at locality 8 and limestone lenses at locality 7 are the only sediments known to occur in the diabase. The limestone, which is black, fine-grained, dense, and has been recrystallized, occurs in lenses in the diabase near the faulted contact with the Digger Island Formation. The shale is yellow-brown and is strongly sheared. Microscopically, the rock consists of iron-stained clay minerals elongated in the plane of the bedding. Chalcedonic silica is present in veins across the bedding and there was also some selective silicification along certain beds.

Age of the diabase. It has been established that the age of the Heathcotian rocks in Victoria is Middle to Upper Cambrian and older (Skeats, 1908; Teale, 1919). The diabase at Waratah Bay appears to be on the same major structural line as the Howqua belt of diabase, and, having similar lithology, it probably is of

the same general age. No fossils were found in the field in the shale at locality 8, but sponge spicules were found in a thin section of this rock. This discovery indicates that additional material might yield new fossils or allow the proper determination of the sponge.

Gabbro

Outcrops of gabbro are restricted to the vicinity of the fault between the diabase and Digger Island Formation. The extent of the gabbro to the west is not known, as it is overlain by Tertiary sediments.

The gabbro is a medium- to very coarse-grained, equigranular, hypidiomorphic, green rock and has been serpentinized. Crystal size is commonly 2 to 5 mm., but at some localities on the backshore west of Digger Island it is as large as 40 to 60 mm. Opal, which probably originated through liberation of silica during the decomposition of olivine, is present in joints, and calcite and limonite are common vein minerals.

Thin sections indicate that the gabbro was originally a group of basic plutonic rocks, rather than one rock type. Newberry (1877), in a laboratory report on specimens from Waratah Bay, records the presence of plagioclase and a uralitized diallage, and named the rock gabbro. This name is retained for convenience until further work indicates the various rock types present.

A section of the medium-grained rock contains serpentine, saussuritized felspar and calcite. Serpentine occurs as complete pseudomorphs after subhedral orthopyroxene, probably enstatite. The saussuritized felspar shows relict twinning and was probably labradorite. Calcite occurs in veins. The coarse-grained gabbro consists largely of subhedral saussuritized felspar and interstitial serpentine after olivine. Serpentine also occurs in veins. Leucoxene is present in the cleavage planes of the pseudomorphic serpentine. The felspar was originally labradorite and shows relict lamellar and Carlsbad twinning.

The intrusion of the gabbro resulted in low-grade thermal metamorphism of the diabase and Digger Island Formation. The gabbro has not been sheared and it is therefore younger than the fault which provided a passage for the intrusion.

Structure

Major Faults

The Palaeozoic formations exposed along the west coast of Waratah Bay are separated by a system of faults with a general northerly trend. Along the shoreline, the fault zones have been severely affected by weathering and therefore little information regarding the nature of the faulting can be obtained.

The Bluff-Point Grinder Fault

At The Bluff, a faulted contact between the Liptrap Formation and Bell Point Limestone has been revealed by the quarrying of limestone. The pug zone is 150 feet wide and dips steeply to the west. It contains lenticular pebbles of limestone, sandstone and mudstone. The Bell Point Limestone, along the eastern face of The Bluff, shows calcite veining over a distance of 150 feet to the east of the fault. The Liptrap sediments immediately to the west of the pug zone are strongly folded and sheared. On the foreshore at The Bluff the pug zone is eroded below the level of the shore platform and is covered by sand; the gap between the sediments on the foreshore strikes 30 degrees and the sediments on either side 10 degrees.

West of Point Grinder, a gap of 160 feet separates the grey-white limestone of the Bell Point Limestone from sandstone of the Liptrap Formation. The limestone within 80 feet of the contact is sheared and fractured and is extensively veined by calcite along the fractures. The dips of the sediments on either side of the gap are steeper than elsewhere, and decrease beyond 160 feet. Calcite veining in the limestone and local steepening of the dip in both formations is regarded as evidence of faulting. In the map (Fig. 3) this fault is shown as the continuation of the fault at The Bluff, which involves the same formations.

Fault between Bell Point Limestone and Diabase

At Point Grinder, the contact of these formations can be studied in plan on the wave-cut platform at low tide over a distance of 1200 feet. The contact is regarded as a fault, because a brecciated zone usually 6 to 8 feet in thickness occurs between the two formations. The diabase is strongly sheared for more than 100 feet from the contact, with west dipping shear planes, although the diabase itself appears to dip steeply to the east. The limestone at the contact contains slickensided calcite along numerous shear planes. The diabase, limestone and brecciated zone in the vicinity of the fault strike at 15 to 20 degrees and dip 55 to 65 degrees to the west. The size of the brecciated fragments in the fault zone range from 1 to 8 cm.

South of Bird Rock, the contact between the diabase and Bell Point Limestone is transverse to the bedding of the limestone and is therefore faulted. Evidence of faulting is substantiated by the partial recrystallization of the limestone and calcite veining, and shearing of the diabase. Boulders of diabase along the contact are impregnated with limonite.

Fault between Digger Island Formation and Diabase

Between localities 6 and 7, a fault zone separates these formations. The gabbro, which is exposed at locality 6 and other localities further north, separates the diabase from the Digger Island Formation, and was intruded along the fault which separates the two formations. The fault zone is nearly vertical, although one reading indicated a steep westerly hade. The limestone east of the fault dips steeply east. The fault zone, with an intimate mixture of sheared diabase, calcite and recrystallized limestone, is 150 feet wide.

Fault between Digger Island Formation and Bell Point Limestone

There are no outcrops in the fault zone separating the Digger Island Formation and Bell Point Limestone between localities 2 and 3, but the outcrops of the Bell Point Limestone adjacent to the fault zone both here and at locality 5 are strongly veined with calcite. Close to the fault, the limestone dips steeply to the east, which is in contrast to the general westerly dip. This indicates the direction of throw of the fault. The limestone is also more folded in the vicinity of the fault than elsewhere, and the folds are commonly fractured, the fractures hading steeply to the east.

Age of the Faulting

The gabbro is younger than the fault between the Digger Island Formation and the diabase. The faults in the area are probably of the same age and connected with the orogenic movements which folded the rocks in the area. Limonite and calcite infilling of joints in the gabbro, with some slickensiding, is probably a

result of later small-scale movements. The main movement pre-dated the deposition of Tertiary sediments because the scarp between Point Grinder and The Bluff is a consequent fault-line scarp and has been partly covered by the Tertiary sediments. West of The Bluff, in the vicinity of the fault contact between the Liptrap Formation and Bell Point Limestone, a bed of Tertiary pebbles has been displaced 12 feet by a downward movement on the western side of the fault. The faulting is post-Devonian sedimentation and pre-dates both the gabbro and the Tertiary sediments, with slight post-Tertiary movement.

Structure of Sedimentary Rocks

Digger Island Formation

Folding in this formation is restricted to shallow cross-folds which are common on Digger Island, making dip and strike readings unreliable. Small-scale faults, which range in strike from 340 degrees to 20 degrees and hade steeply in a westerly direction, were observed on Digger Island. On the eastern side of the island, calcite is associated with horizontal slickensides along the fault planes. Fossils are commonly sheared.

Two sets of joints, almost at right angles, are developed in the outcrops on Digger Island. The trends are north-north-west and east-north-east and dips are steep to the west and north. Jointing is well developed in the contact metamorphic zone with the gabbro.

Bell Point Limestone

The main structural trends of this formation are illustrated in Fig. 2. The folds are shallow and usually in the nature of asymmetrical flexures, which plunge to the north. The folding is more intensive near the major fault separating the formation from the Digger Island Formation, but the folds remained shallow and relief of compression was affected by small break thrusts of a few feet.

Jointing is well developed near the faulted contact with the diabase near Bird Rock.

Liptrap Formation

The sediments of this formation are strongly folded, but the folds have not been mapped as this would involve much detailed work. Near Cape Liptrap, the cliff sections at the heads of the rocky coves illustrate the complexity of the folding. In general, the strike ranges from north to 30 degrees, with dips rarely less than 60 degrees and frequently approaching 90 degrees. At Point Grinder, the beds are vertical or dip steeply west for some distance to the west of the faulted contact with the Bell Point Limestone, and easterly dips are rare.

The beds are sheared and tension gashes filled with quartz have been observed associated with quartz veins in the medium- and coarse-grained sandstones. The fine-grained sediments are commonly fissured at the apices of folds and in crush zones. Dip faults and oblique faults are common.

Numerous beds of dark-grey and black mudstone are closely folded, sheared and contorted. Incorporated within these beds are thin layers of medium and coarse sand, large blocks and balls of sandstone and mudstone, and numerous pebbles of well rounded and tabular quartz and slate. The folding was produced by subaqueous penecontemporaneous slumping, because the overlying and underlying beds conform with the regional structural pattern.

STRUCTURE OF IGNEOUS ROCKS

Diabase

The structures and textures of the igneous rocks are largely obliterated as a result of diastrophic movements. The associated pyroclastic rocks and interbedded sediments give the only structural indications.

Dips are steeply to the west or vertical except for a steep easterly dip of a bed of chert at locality 12, and in strongly sheared tuffs near the faulted contact with the Bell Point Formation at Point Grinder. Faults have been observed at localities 9, 10 and 11. The formation is strongly but irregularly jointed. Main trends of faults and joints are northerly and approximately 100 degrees.

Gabbro

The gabbro is massive and, as mentioned before, evidently younger than the fault between Digger Island Formation and the diabase. Calcite and limonite veins along the numerous joint planes in the weathered gabbro give it a honeycombed appearance. The largest of these joints trend northerly and show near-horizontal slickensiding of the calcite.

CONCLUSION

The most obvious feature of the structure of the three Palaeozoic sedimentary formations at Waratah Bay is that folding has been most intensive in the Liptrap Formation and least noticeable in the oldest formation, the Digger Island Formation.

Ferguson has mapped Upper Ordovician fossiliferous slates and sandstones 4½ miles north-west of Walkerville, near Ten Mile Creek and at Bald Hill, further north. The continuation northwards of this belt of Ordovician has been termed the Waratah-Boolara Anticlinorium (Thomas, 1939). The belt of diabase along the Waratah Bay coastline has been termed the Waratah Axis. In between these structural axes, with Lower Palaeozoic rocks exposed in the cores, is a belt of closely folded Devonian sediments with predominating westerly dips between Point Grinder and Cape Liptrap. This suggests a synclinal area, five miles across, defined by boundary faults against the Waratah Axis so that rocks of Ordovician and Silurian age are not exposed on the east side of the synclinal area west of the Waratah Axis. Baragwanath (1925) has suggested the possibility of a continuation of the Walhalla Synclinorium to the south as far as Cape Liptrap.

Geomorphology

CAPE LIPTRAP PENINSULA

The streams draining the eastern side of the peninsula are deeply incised into a low scarp between Point Grinder and Walkerville and into a small plain which extends from the base of the scarp at about 200 feet above sea level, to the coastline. The streams are consequent with steep-sided, straight valleys and little or no accumulation of alluvium in the valley floors. The interfluves are wide and there is little development of insequent tributaries reducing the width of the interfluves. Bear Creek is an example of an engrafted stream. The plain is still in the stage of early youth.

If the distribution of sands, clays and gravels marked Tertiary on Ferguson's plan is correct, and this has been partly verified by examination along the coast and in some creek beds on traverses inland, then the plain can be envisaged as a

coastal plain, following a late Tertiary emergence of a marine platform, of at least 150 feet. Torrent gravels, with well rounded quartz pebbles, occur about 140 feet above sea level at Bairnsdale. Tertiary sediments occur up to 250 and 270 feet above sea level at Fernbank between the Avon and Mitchell Rivers, in the neighbourhood of the Gippsland Lakes (Hart, 1922). The East Gippsland coastline was uplifted in post-Lower Pliocene time and is now being modified by submergence.

Coastline

Structure and the various rock types influence the configuration of the coastline. Between Point Grinder and Cape Liptrap and north of The Bluff the coastline is either sub-parallel to or normal to the consistent regional strike of the Liptrap Formation (Fig. 3). South of The Bluff the coastline is mainly in the structureless diabase, and swings in a south-east direction to Bell Point and then to the south-west to Point Grinder. The headlands are composed of sandstone (Cape Liptrap) and limestone (Point Grinder, Bell Point, Bird Rock). The sandstone cliffs are higher than those of limestone. The diabase shoreline is rocky, with frequent gaps a few feet wide forming deep clefts to the backshore or the base of the cliffs. Occasional open stretches occur along the shore, but these are not large enough to be termed pocket beaches. Landslips occur in the cliff regions of the diabase when the cliffs are undercut by wave action on the deep-weathering diabase.

Wave-cut Platforms

The influence of rock types and power of wave action in the formation of wave-cut platforms is well exhibited. The grey-white limestone of the Bell Point Limestone at Point Grinder, Mushroom Rock and Bird Rock has a well developed and level platform, truncating beds which dip from 65 degrees to 25 degrees and strike in varying directions. Wave-cut notches at the base of the cliffs are also well developed. On the exposed sides of Point Grinder (south-west) and Mushroom Rock (east) the platform is narrow. On the eastern side of Point Grinder, which is sheltered from the heavy seas and south-westerly gales of Bass Strait, the wave-cut platform extends from the limestone cliffs to the faulted contact with the diabase. Platforms on the grey limestone of the Bell Point Limestone are poorly developed, although structural conditions are similar to those of the grey-white limestone. The platforms are narrower, have an uneven surface, and merge with the cliffs and stacks at high water level without the development of wave-cut notches.

An extensive platform is formed on the sediments of the Liptrap Formation at the head of the broad bay between Point Grinder and Cape Liptrap, where the shoreline is normal to the consistent strike of steeply or vertically dipping sediments. The platform has a peculiar appearance at low tide, as selective erosion of alternately bedded shale and sandstone has given the appearance of a coarsely ploughed field. Near Cape Liptrap, where the shoreline is parallel to the strike, the wave-cut platform is absent or poorly developed as selective erosion of the sediments has left the massive sandstone beds protruding as bars and rocks.

The surface of outcrops of diabase is very uneven along the shoreline. Selective erosion along ash beds, shear zones and irregularly spaced joints has prevented the formation of a platform, but there is a general upper surface, which is capped only rarely by a harder mass of diabase, shelving gradually seawards.

There is no wave-cut platform on sediments of the Digger Island Formation.

Storm Beach

A storm beach occurs at the head of the broad bay between Point Grinder and Cape Liptrap. The beach consists of well rounded cobbles and pebbles and is 8 to 10 feet above high water level. It is being overgrown by vegetation on the landward side. Thick-shelled molluscs, usually *Haliotis,* casing wood and other flotsam from passing ships lie on the beach platform. The shells, corroded and stained on the head of the beach, are much fresher and cleaner near the seaward edge of the beach. This affords evidence that the beach is still enlarging, although calm seas attack the base of the beach deposit, which has a steep seaward profile, approaching the angle of rest of the pebbles.

Sub-aerial Weathering

The occurrence of water-level or water-layer weathering (Bartrum and Turner, 1928; Hills, 1949) was observed on the diabase. Sub-aerial weathering has produced shallow pools on the diabase between Bird Rock and locality 1. The pools are at about high water level and several feet above—within the range of spray. The pools, with typical horizontal water-layered surfaces, usually originated in the joint planes of the diabase. These pools have not been observed on outcrops of the other formations.

Extensive etching of the limestones of the Bell Point Limestone and the Digger Island Formation, where they are subjected to the action of spray above high water level, has resulted in a *karren* surface. This is particularly noticeable at Bell Point, the rocks of dark-stained limestone off locality 7 and at Point Grinder.

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6

MESOZOIC AND TERTIARY SEDIMENTS FROM THE WAHGI VALLEY, NEW GUINEA

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[Read 13 December 1951]

Introduction

The object of this paper is to present the results of a petrological study of the thick series of Mesozoic and Tertiary sediments exposed in the Lower Wahgi Valley, in the Chimbu-Hagen region of New Guinea (Fig. 1), and to discuss these results in relation to the available stratigraphic, palaeontological and regional data on the Chimbu Mesozoic section, which provides a useful standard for a sedimentary series of considerable geological interest.

The work derives from a detailed geological survey traverse of the Lower Chimbu and Lower Wahgi Valleys, in the Central Highlands of New Guinea, made in 1939 by Mr. L. C. Noakes, who was then Assistant Geologist of the Territory of New Guinea. This area had not been examined previously in detail. Dr. N. H. Fisher had visited the Wahgi Valley in his capacity of Government Geologist, and had collected some fossils, which were described by Miss I. Crespin (1938). Dr. K. Washington Gray visited the area early in 1939 and collected fossils and fossiliferous rock specimens, which were examined by Dr. F. W. Whitehouse and one of the writers (M.F.G.).

A report by Noakes (1939) was distributed in mimeographed form by the Territory of New Guinea authority, but has not yet appeared in print. Miss Crespin examined palaeontologically a series of rock specimens collected by Noakes, and a duplicate set was studied by one of us (M.F.G.) in 1940. Some results of this investigation are included in a publication on Mesozoic fossils from New Guinea (Glaessner, 1945). This duplicate set of specimens was lost in New Guinea during the war, except for a few Jurassic mollusca described in the 1945 publication.

A petrological examination of a suite of representative samples from Noakes' collection, which is preserved in the collections of the Commonwealth Bureau of Mineral Resources at Canberra, was made by one of us (A.B.E.) in 1949, and issued as a mimeographed report of the Commonwealth Scientific and Industrial Research Organization (Edwards, 1949). This, in a revised form, is the basis of the present study, and is published by permission of the C.S.I.R.O.

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Stratigraphy of the Wahgi-Chimbu Section

The total thickness of sediments exposed along the Lower Chimbu and Lower Wahgi Valleys is about 22,500 feet (Noakes, 1939). The topmost formation is the Lower Tertiary Chimbu Limestone, about 600 feet thick. The beds strike east-south-east, and dip in a northerly direction throughout, the angle of dip decreasing from about 45° near the Chimbu Limestone, to less than 20° near the base of the series. Noakes reports that shales and mudstones greatly predominate

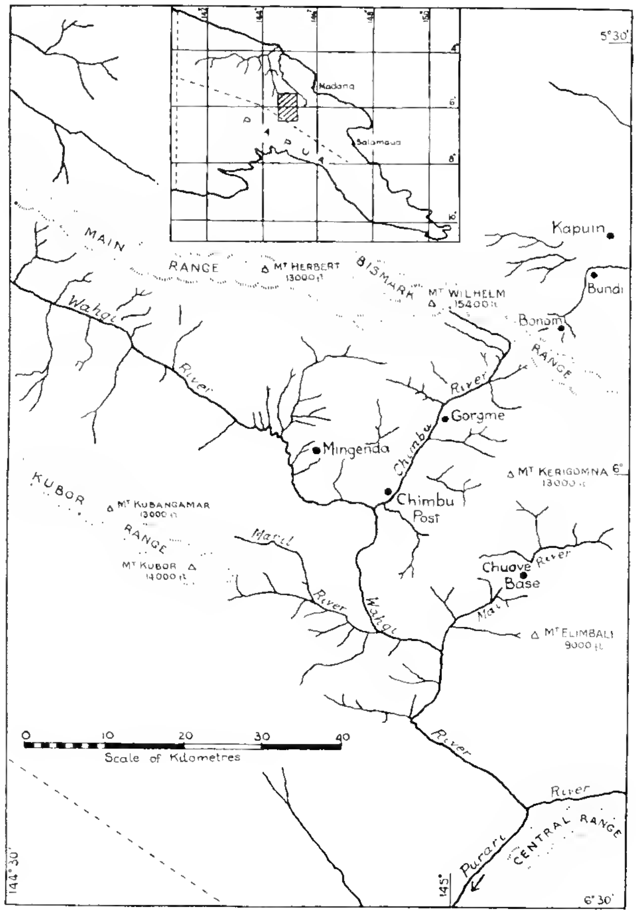

FIG. 1.

in the section, but that beds of fine-grained sandstone, some of them tuffaceous, are well distributed over the section (Fig. 2), and usually show a gradual transition to the finer sediments. Occasional grit and pebble beds mark coarser phases of the sandstones, and two horizons of conglomerate, with a total thickness of about 100 feet, were mapped. One horizon of water-sorted volcanic agglomerate was noted.

Apart from the Chimbu Limestone at the top of the section, limestones are restricted to four thin beds in the upper 10,000 feet of the section. In the lower 12,500 feet there is only a little impure limestone or calcareous slate near the base

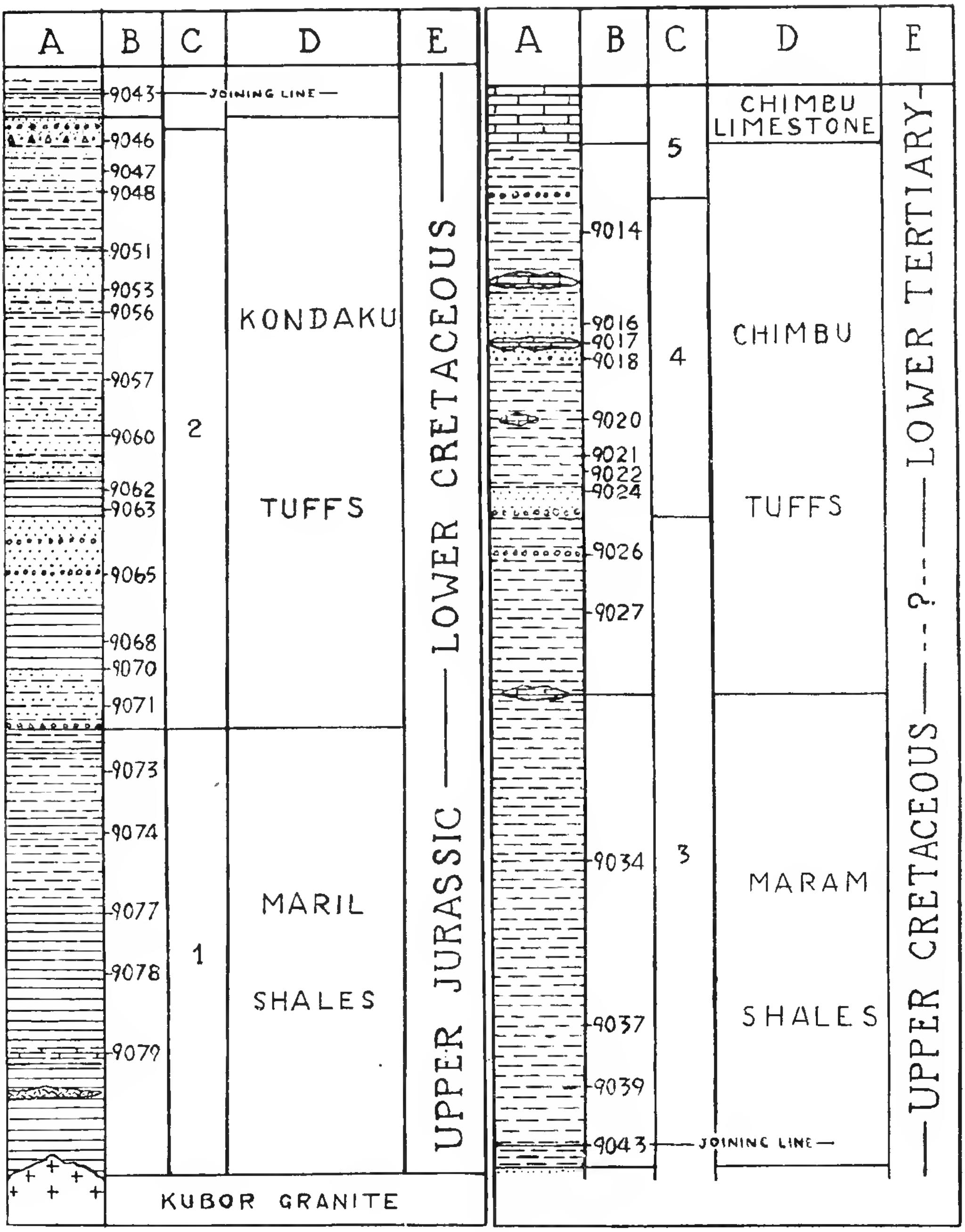
A
B
C
D
E
9043
JOINING LINE
9046
9047
9048
9051
9053
9056
9057
9060
9062
9063
9065
9068
9070
9071
9073
9074
9077
9078
9079
2
1
KONDAKU
TUFFS
MARIL
SHALES
UPPER JURASSIC — LOWER CRETACEOUS
KUBOR GRANITE
CHIMBU LIMESTONE
5
4
3
9014
9016
9017
9018
9020
9021
9022
9024
9026
9027
9034
9037
9039
9043
CHIMBU
TUFFS
MARAM
SHALES
UPPER CRETACEOUS --?-- LOWER TERTIARY

Fig. 2.

of the series. There are also occasional bands of chert. Near the base of the series, also, there is an intrusive sill of fine-grained diorite, between 100 and 200 feet thick; and elsewhere there are small dykes and lenticular bodies of granodiorite intrusive into the sediments.

TABLE 1

Classification of Specimens from the Wahgi-Chimbu Section

Specimen No.	Field No. (Noakes' Report).	Depth in feet of horizon below top of Chimbu limestone.	Description.
9014	6	1,530	Sandy tuff.
9016	86	2,470	Tuff.
9017	85	2,650	Foraminiferal limestone.
9018	84	2,840	Sandy tuff.
9020	8	3,480	Tuffaceous mudstone or tuff (puckered).
9021	9	3,850	Tuffaceous mudstone or tuff.
9022	82	4,010	Fine-grained sandy tuff.
9024	11	4,290	Zeolitic tuff.
9026	12	4,920	Coarse zeolitic tuff, with chloritic ovoids.
9027	13	5,540	Tuffaceous mudstone.
9034	19	8,110	Fine-grained greywacke.
9037	21	9,860	Mudstone.
9039	23	10,510	Fine-grained greywacke.
9043	27	11,120	Greywacke.
9046	30	11,580	Coarse greywacke or grit.
9047	31	11,850	Greywacke grading into sandy tuff, or sandy tuff.
9048	32	12,080	Greywacke grading into sandy tuff, or sandy tuff.
9051	35	12,730	Sandy tuff, zeolitic.
9053	36a	13,115	Sandy tuff, zeolitic.
9056	36d	13,385	Sandy tuff, zeolitic.
9057	37	14,080	Sandy tuff, zeoliticì (with ?slump structures).
9060	40	14,670	Tuffaceous mudstone or tuff.
9062	42	15,240	Tuffaceous mudstone or tuff.
9063	43	15,530	Sandy tuff.
9065	45	16,080	Tuffaceous mudstone.
9068	48	16,820	Greywacke.
9070	50	17,075	Coarse tuff, or fine agglomerate.
9071	51	17,510	Coarse tuff, or fine agglomerate.
9073	53	18,180	Chert (radiolarian).
9074	54	18,810	Chert (radiolarian).
9077	57	19,540	Shaly limestone, or red calcareous shale.
9078	58	20,280	Calcareous shale or fine greywacke.
9079	59	21,140	Calcareous shale or fine greywacke.
9087	78	Kubor Range, 5,500 ft. elev.	Calcareous shale with shells or shaly limestone.
9093	91	Chimbu River, 2½ miles above Gorgme Base Camp.	Ferruginous shale.
9094	92	Chimbu River, 1¼ miles below Gemboge Mission.	Sandy shale.

The lithological variations in the section are slight, but Noakes tentatively subdivided the series into five stages:

(1) Stage 1, the basal stage, comprising 4,500 feet of slates and shales.
(2) Stage 2, comprising 6,200 feet, of which about half is sandstone or sandy shale.
(3) Stage 3, comprising 6,500 feet of shales and sandstones, with a minor limestone horizon in the upper half, and representing a passage from Upper Cretaceous to Eocene.
(4) Stage 4, commencing with grit and pebble beds, and consisting of 4,000 feet of shales and fine sandstones, with some beds of limestone.
(5) Stage 5, about 1,100 feet thick, beginning with a bed of conglomerate, and comprising fine sediments and the Chimbu Limestone, here about 600 feet thick.

TABLE 2

Stratigraphic Subdivisions of the Wahgi-Chimbu Section

Noakes Stages	New Names	Lithology	Approximate Thickness (ft.)	Age
5	Chimbu Limestones.	Foraminiferal limestones.	600-	Lower Oligocene to Upper Eocene.
4	Chimbu Tuffs.	Tuffs and tuffaceous mudstones with foraminiferal limestone bands and lenses.	5,700	Eocene (and Upper Cretaceous ?).
3	Maram Shales.	Shales and mudstones with subordinate fine greywackes.	5,200	Cenomanian.
2	Kondaku Tuffs.	Tuffs, tuffaceous mudstones and greywackes.	6,100	Lower Cretaceous.
1	Maril Shales.	Siliceous and calcareous shales.	4,500	Upper Jurassic.

Individual sandstone horizons, as shown in his lithological column, range from 200 to 800 feet thick. The suite of specimens studied petrologically represents Noakes' Stages 1 to 4, but not his Stage 5. The positions of the specimens in the lithological column are shown in Table 1. The numbers, 9014 to 9079, refer to the registered numbers of the specimens in the collection of the Bureau of Mineral Resources (Canberra).

Noakes' field divisions of this thick series of conformable sediments was based chiefly on his interpretation of a few coarser beds as indicators of minor diastrophic movements. The petrological investigation had led to a different view of the nature of these sediments, and makes it possible to re-define the stratigraphic divisions on the basis of changes in the constitution of the rocks. This involves shifting the boundaries between Noakes' tentative Stages 3, 4 and 5 to horizons of lithological change. Taking into consideration the lithological characters of the rocks, and the results of palaeontological studies, as described herein, and following

the new Code of Stratigraphic Nomenclature (Raggatt, 1950), we have named and tabulated Noakes' field stratigraphic subdivisions as shown in Table 2. The names of native villages and a stream (Maril), in the vicinity of the outcrops, were selected from unpublished maps in consultation with Mr. Noakes. Some further adjustments of the boundaries may become necessary when gaps in sampling are filled and the uncertain positions of some samples, particularly the positions of limestone bands and lenses in the upper part of the section, are rendered more precise.

Summary of Palaeontological Observations

Studies of the various collections of fossils made from the area have revealed that the sediments range in age from Upper Jurassic to Lower Oligocene.

Upper Jurassic

Numerous well-preserved specimens of the mollusc *Buchia malayomaorica* (Krumbeck) were found in a dark red shale about 2,700 feet above the base of the Wahgi-Chimbu section (Glaessner, 1945, p. 154, Pl. 6, Fig. 7). This species is known from many localities in the area between Celebes and New Zealand. In the eastern part of the Sunda Archipelago its age was determined as Oxfordian (Upper Jurassic). It is commonly accompanied by *Belemnopsis gerardi* (Oppel), but this species has not yet been found in the Wahgi Valley. Only fragmentary *Inoceramus* and other bivalves occur here with *Buchia*. Abundant radiolaria and sponge spicules were recorded by Miss Crespin from the upper 1,300 feet of the Maril Shales.

Lower Cretaceous

Most of the samples from the second division, the Kondaku Tuffs, are unfossiliferous. Miss Crespin recorded occasional radiolaria from the lower 2,500 feet of these beds. Worm burrowings were observed in a sample from the middle of this sequence, and occasional *Globigerina* and radiolaria are also recorded. The upper 1,500 feet of strata contain fragments of *Ostrea sp.*, *Pseudavicula sp.*, and plant remains, which occur in some abundance. These fossils support the correlation with the Purari Formation.

Recently a number of fossils collected by natives from near Masul, a village about three miles east-south-east of Chimbu air strip, were presented to a geological survey party led by Mr. G. A. V. Stanley. These fossils included eight specimens of a large *Deshayesites n.sp.*, four specimens of *Cymatoceras sp.*, a fragment of a large belemnite phragmocone resembling *'Belemnites' sellheimi* Tenison-Woods, and nineteen specimens of *Pleuromya n.sp.*, which are specifically identical with the *'Panopaea'* or *'Pleuromya'* described by Erni (1944) from the area of the Gende tribe, near Bundi on the north-east slope of the Bismarck Mountains. These fossils are definitely Lower Cretaceous, the *Deshayesites* indicating Lower Aptian age. Two Cenomanian ammonites were obtained in the same manner from the same general locality (see below).

In the course of a geological traverse on behalf of Island Exploration Company, Mr. Stanley found other Lower Cretaceous fossils about eleven miles south-east of Chimbu (in the direction of the regional strike). These include a *Puzosia sp.*, about 16 inches in diameter, a large *Cymatoceras sp.*, and several specimens of *Aucellina gryphaeoides hughendenensis* (Etheridge). The fossils were found in some of the abundant calcareous nodules in shales which contain a large fauna of

smaller foraminifera. This fauna will be described elsewhere. The *Aucellina*, which is a characteristic fossil of the Tambo formation of the great Artesian Basin of Australia, and some of the foraminifera, such as the distinctive *Pleurostomella reussi* Berthelin, indicate Albian age. These collections were taken from concretions in tuffaceous mudstones. They support the placing of at least part of the Kondaku Tuffs in the Aptian and Albian.

Upper Cretaceous

According to Noakes (1939), the Mingenda ammonite horizon corresponds to the lower part of his Stage 3. The ammonite locality at Mingenda airstrip and Korigu village has yielded *Euomphaloceras hoeltkeri* (Erni), described as *'Cunningtoniceras'* by Erni (1944), occurring commonly together with *Puzosia sp.*, *Turrilites cf. scheuchzerianus* Bosc, and *Inoceramus sp.*, which were identified by F. W. Whitehouse, and a few foraminifera, including *Textularia cf. washitensis* Carsey. This is a Cenomanian fauna. Noakes' samples from the Chimbu section contained only a few foraminifera, including the same *Textularia*. Two ammonites collected by natives, together with the Aptian fauna, apparently as stream pebbles in a short south-east tributary of the Chimbu Valley, are a *Mantelliceras sp.* and a fragment of a whorl of *Turrilites cf. acutus* Passy, a well-known Cenomanian form.

Eocene

From a limestone shown on his map as a lens 1,000 feet long and 150 feet wide, Noakes obtained a sample containing Eocene Nummulites. He believed this to be identical with the rock from which Fisher had collected a sample with *Lacazina, Biplanispira, Pellatispira,* and other Eocene foraminifera (Crespin, 1938). Noakes concluded that his Stage 3 represented a record of uninterrupted sedimentation from Upper Cretaceous into Lower Tertiary time. This now appears questionable.

The distinctive faunas so far found are as low in the Upper Cretaceous as Cenomanian, and as high in the Tertiary as Middle or Upper Eocene (probably Late Eocene), without any representatives of Turonian, Senonian, Danian, Paleocene or Lower Eocene. There is also some uncertainty as to whether the limestone lens from which the sample was taken was *in situ.*

There is, however, a lithological difference between the samples examined from beds below and above this limestone. The samples from about 1,750 to 5,200 feet below the limestone are greywackes and mudstones, while the samples from 800 to 4,800 feet above it are tuffs and tuffaceous mudstones, containing in the upper 1,000 feet of this section further limestone bands with Upper Eocene, and possibly Lower Oligocene, foraminifera. A formation boundary is drawn tentatively at the approximate horizon of this change between the Maram Shales below and the Chimbu Tuffs above. If the lowest limestone 'lens' recorded by Noakes was not *in situ,* then the Chimbu Tuffs could still contain a record of uninterrupted sedimentation from the Uppermost Cretaceous (Upper Senonian), which is well represented in the Central Highlands, to Eocene, but otherwise they must be entirely Eocene. A representation of the entire sequence from Cenomanian to Eocene in the 5,200 feet of uniform Maram Shales and fine greywackes is considered unlikely. Fossils found in this part of the section are poor, and further collections are desirable.

Stratigraphic Correlation

A tentative correlation (Glaessner, 1945, Table 1) of the lower 17,200 feet of the Wahgi-Chimbu section placed the first stage, here called Maril Shales, in the Upper Jurassic. The Jurassic extends westward from the Wahgi-Chimbu section to the international border, and into Netherlands New Guinea, where similar faunas have been recorded from a number of localities. It has not been observed east of Chimbu.

The gap which appeared to exist regionally between Upper Jurassic and the lowest fossiliferous horizon in the Lower Cretaceous has been reduced by the discovery, about 75 miles south of Chimbu, in Papua, of a fauna with *Neocomites* and *Streblites,* apparently of basal Cretaceous age. This will be described by Dr. L. F. Spath. The siliceous beds at the top of the Maril Shales, or the basal part of the Kondaku Tuffs, may represent the basal Cretaceous.

The Kondaku Tuffs can be correlated with the Purari Formation. Fossils of Aptian or Albian affinities were found in the upper part of the Purari Formation (Glaessner, 1945), but its base was not exposed at the type locality (Carey, 1945). In view of the conformable sequence in the Wahgi-Chimbu section, the entire Lower Cretaceous could well be represented here, but unfortunately most of it is unfossiliferous, although the occurrence of Aptian and Albian was confirmed by the discoveries of fossils within a few miles of the section, leaving no doubt of the existence of a conformable sequence from the Lower Cretaceous tuffs to the Cenomanian shales, with an unbroken transition from Albian to Cenomanian. Rich faunas of Albian and Cenomanian smaller foraminifera have been found at various localities in the Wahgi Valley and in western Papua, so that further detailed work may make it possible to study such faunas from a single section. The foraminiferal assemblages are similar to those recorded in recent years from the southern Alps. North Africa, and Texas, where detailed zoning has been carried out, so that it will then be possible to give a more exact date for the change from tuffs to greywackes, which takes place in the vicinity of the Albian-Cenomanian boundary.

The lower part of the Chimbu Tuffs cannot be dated palaeontologically, as yet. and has not been recognized elsewhere; and there is as yet no palaeontological evidence of the occurrence in the Wahgi-Chimbu section of the Upper Senonian. which is widely distributed throughout New Guinea.

The Tertiary begins generally with Middle or Upper Eocene limestones, commonly containing *Lacazina, Pellatispira,* or *Biplanispira*, and resting on Cretaceous or on pre-Mesozoic basement rocks. In the Wahgi-Chimbu section these limestones seem to grade up into Lower Oligocene, and to lens out downward, and possibly westwards (Noakes, 1939), into tuffaceous sediments.

Petrology

The specimens studied petrologically include sandstones, mudstones, shales, cherts and limestones, with mudstones and sandstones prevailing. The sandstone members of the Wahgi series tend to be fine-grained, and are all more or less tuffaceous. They range between two extremes — quartz-rich greywackes and andesitic tuffs, with a number of the specimens predominantly tuffaceous, but showing an intermingling of source materials. The mudstones grade into the sandstones as regards grain size, and are composed of generally similar materials. A number of the specimens are more or less weathered, and the unweathered specimens are too well cemented for reliable sizing analyses to be made.

Greywackes

The greywackes are represented by specimens Nos. 9043 and 9068, a coarse greywacke or grit, No. 9046, and sandy mudstones, Nos. 9034 and 9039. They occur, therefore, in both the Upper and Lower Cretaceous (Table 1), with 9043 more or less marking the divisions between the two periods.

Specimen No. 9043 consists of grains of quartz, felspar, biotite, muscovite, chlorite, glauconite, and leucoxene, together with numerous fragments of fine-grained andesite, phyllite, shale, quartzite, and chert, in an abundant cement of carbonate, that appears to have replaced much of the original fine matrix and parts of the grains and rock fragments. The average size of the grains and fragments is about 0·25 mm., but the rocks are ill-sorted, and occasional grains, and particularly the fragments of shale, are up to 1 mm. long.

Quartz is the most abundant of the mineral grains. It occurs as fragments up to 0·5 mm. by 0·5 mm., with a tendency to be equidimensional. Some grains are well rounded, or partly rounded, with overgrowths of quartz, but the majority were angular before the development of the overgrowths (Pl. III, fig. 1). Others show partial replacement by the carbonate cement.

The felspar includes both orthoclase and plagioclase, but tends to be extensively replaced by the carbonate cement, so that it is difficult to assess their original proportions. Plagioclase is now the more abundant, occurring chiefly as stumpy prisms or laths, up to 0·3 mm. by 0·2 mm., or as fragments of such crystals. It shows broad lamellar twinning, with an extinction angle of about 10°, so that it is presumed to be oligoclase.

The biotite is a brown variety, though some flakes are pleochroic from green to brown. Some flakes have a weathered appearance. They are about 0·5 mm. by 0·1 mm., and tend to lie parallel to the bedding. Commonly they are bent through having been 'nipped' between other grains during compaction. In places the biotite is largely or completely altered to chlorite. The muscovite occurs as occasional flakes, less abundant than the biotite, but occurring in much the same way.

Glauconite is a minor but conspicuous component, occurring as well-rounded grains about 0·2 mm. by 0·1 mm. The majority are a bright green, with a typical cryptocrystalline appearance, in low colours, under crossed nicols. Some grains appear somewhat oxidized.

Brown tourmaline is present as occasional rounded grains, up to 0·2 mm. across, and there are occasional grains of zircon visible in thin sections. In addition there are grains of leucoxene, more or less rounded.

Of the abundant rock fragments, andesite, shale and phyllite are the chief components. The andesites are fine-grained varieties, with numerous microlites of plagioclase laths showing straight extinction, and commonly with parallel alignment, in a colourless to greenish glassy base. Occasional fragments are porphyritic, with microphenocrysts of sodic plagioclase. A few are studded with chlorite, presumably an alteration product of original finely divided femic minerals. The majority of the andesite fragments are equidimensional and well rounded. Fragments as large as 0·5 by 0·5 mm. occur, but 0·2 mm. by 0·2 mm. is a more common size. A few fragments are angular or sub-angular.

The phyllite and shale fragments, by contrast, are mainly anisodimensional. Coarse fragments are 1·0 mm. by 0·25 mm., but most are smaller than 0·5 mm. by 0·2 mm. The elongation is always parallel to the bedding or cleavage of the fragment. The majority of the shale and phyllite fragments are well rounded (Pl.

III, fig. 2). Some are carbonaceous, with films of carbonaceous material as a cement between the grains, and extending parallel to the bedding. The phyllite fragments contain an abundance of fine-grained biotite, in some instances chloritized.

The quartzite and chert fragments are generally smaller than the shale fragments, and are more nearly equidimensional, averaging about 0·2 mm. by 0·2 mm. Some are rounded, but as many are angular. The predominantly rounded form of the rock fragments is in marked contrast to the angular shape of the mineral grains. This arises, presumably, from the softer and more friable nature of many of the rock fragments as compared with the mineral grains. It indicates transport for the rock components as a whole.

Specimen No. 9068 (Pl. III, fig. 3) is generally similar to No. 9043, but contains in addition to the minerals listed above a number of grains of yellow epidote, of angular shape, and apparently authigenic. It contains more quartz than No. 9043, and fewer rock fragments, especially andesite.

Specimen No. 9046 is a coarse greywacke or grit. It is a grey rock spotted with fragments of andesite and black slate from 2 mm. to 5 mm. across. Some of the andesite fragments are deeply weathered, and a limonitic brown colour. The rock is severely carbonated, with seams of calcite in the joints. In thin section it appears as a coarser variation of No. 9043. The quartzite fragments are generally rounded, and vary somewhat in size. Some are composed of individual grains up to 0·2 mm. across, others are microcrystalline. The phyllite fragments are well rounded, but notably elongated, and tend to contain much carbonaceous matter. Andesitic fragments are more numerous than sedimentary fragments, and tend to be equidimensional and rounded or angular. One fragment showed partial replacement by glauconite.

Specimens Nos. 9034 and 9039 consist of extremely fine-grained greywacke, or coarse mudstone. In thin section they are of similar composition to No. 9043, the glauconite grains in particular being conspicuous.

Heavy Minerals

The heavy minerals of Nos. 9043 and 9068 were separated in acetylene tetrabromide of Sp.Gr. 2·90 from samples crushed to pass an 0·5 mm. aperture. Both specimens yielded relatively small heavy fractions, but these contain a variety of minerals, many of them water-worn, and some very perfectly rounded. The minerals present are topaz, tourmaline, zircon, apatite, biotite, rutile, garnet, glauconite, pyroxene, leucoxene, iron ores, epidote, carbonate and sulphides. The grain size of these mineral grains ranges from 0·02 mm. to 0·10 mm. diameter.

The topaz occurs as well rounded grains about 0·05 mm. to 0·10 mm. across, generally with a finely pitted surface. Some grains appear almost circular in cross-section, but others are rounded prisms. Grains with low polarization colours yield a positive biaxial figure, with 2V about 45°, which distinguishes them from similar grains of apatite.

The apatite, which is abundant, occurs partly as well rounded, pitted grains about 0·05 mm. diameter, and partly as small prismatic crystals from 0·02 to 0·05 mm. long. Many of these show no sign of water wear, and a few have dark to opaque cores. The small crystals may be derived from the biotite flakes of the rocks, being liberated during crushing.

The tourmaline occurs partly as well rounded grains, partly as prisms, which generally have their angles rounded. Three distinct varieties are present, one which is pleochroic from golden-brown to colourless, one which is pleochroic from

smoky brown to grey-brown, and one which is pleochroic from deep to pale blue (indicolite). The blue variety occurs as well rounded grains, but the golden-brown and smoky varieties occur both as prisms and as well rounded grains.

Zircons are numerous. They are colourless, and mostly small, ranging from 0·02 to 0·05 mm. across. A few grains have a double-ended prismatic form, but squat pyramidal forms predominate. A few grains show perfect crystal shape, but most have their angles well rounded, and some are almost spherical.

The garnet includes colourless, brown, and pink varieties, some of the grains being clearly fragments of larger waterworn grains fractured during crushing. Others are sub-rounded or rounded small grains.

Biotite is an abundant constituent, particularly in No. 9043. It ranges from fresh brown biotite to pale greyish or greenish chloritized flakes. Glauconite is relatively abundant, more so in No. 9043 than in No. 9068. Rutile, on the contrary, appears more abundant in No. 9068. It occurs mostly as angular fragments broken from occasional larger grains. The leucoxene is abundant, generally as waterworn grains, and occasional grains of waterworn magnetite are also present.

Pyroxene occurs as a number of grains of colourless or green augite, all as angular fragments. Carbonate is present as numerous angular fragments broken from the cement, and there are occasional angular fragments of yellow epidote. A few particles of sulphide (pyrite or marcasite) occurred in No. 9068.

TABLE 3

Chemical Analyses of Some Wahgi-Chimbu Sediments

	Wahgi-Chimbu Sediments		Purari Greywacke	Aure Greywacke	
	Greywacke (9068)	Zeolitic Tuff (9024)	(U.P. 125)	(U.K. 1042)	
	1	2	3	4	4a
SiO_2	72·83	50·16	65·18	53·30	57·72
Al_2O_3	10·92	19·63	13·85	18·33	19·85
Fe_2O_3	0·13	2·59	1·30	2·41	2·61
FeO	4·88	2·15	5·43	2·36	2·55
MgO	1·09	1·96	1·87	2·62	2·85
CaO	2·06	8·31	0·72	5·88	5·39
Na_2O	1·20	0·20	1·48	2·18	2·36
K_2O	1·36	1·56	1·60	1·72	1·86
H_2O + 110° C. ..	2·03	9·22	3·94	3·14	3·40
H_2O − 110° C. ..	0·65	2·57	2·10	5·74	—
CO_2	1·00	tr.	tr.	1·00	—
TiO_2	0·72	0·90	0·90	0·84	0·91
P_2O_5	0·35	0·38	0·38	0·28	0·30
MnO	0·03	0·06	0·22	0·08	0·09
Cl	0·03	0·05	0·16	0·03	0·03
SO_3	0·46	0·09	0·90	0·08	0·09
	99·74	99·84	100·08	99·99	

1. Greywacke, No. 9068, from a horizon in the Kondaku Tuffs, 16,820 feet below the top of the Chimbu Limestone, Lower Wahgi River, New Guinea (Lower Cretaceous).
2. Zeolitic Tuff, No. 9024, from a horizon in the Chimbu Tuffs, 4,290 feet below the top of the Chimbu Limestone, Lower Wahgi River, New Guinea (Eocene).
3. Purari Greywacke (U.P. 125), (Edwards, 1950, *Proc. Roy. Soc. Vic.*, 60: 169).
4. Aure Greywacke (UK. 1042), (Edwards, 1950, *Proc. Roy. Soc. Vic.*, 60: 139).

4a. Analysis 4 recalculated free of $CaCO_3$ and H_2O — 105° C.

Analyst: Messrs. Avery & Anderson (Melbourne).

Chemical Analysis

A chemical analysis was made of Specimen No. 9068, which was selected on account of its freshness and relative freedom from carbonate cement. The analysis (Table 3, Analysis No. 1) provides further evidence of the 'mixed' or argillaceous character of the rock, in the presence of nearly 11 per cent of Al_2O_3, 2·5 per cent of alkalis, and 6 per cent of FeO and MgO.

The analysis shows the rock to be rather more siliceous than the typical Lower Cretaceous Purari greywacke (Table 3, Analysis No. 3) described by Edwards (1950), but similar to it in other respects. Of the greywackes in the Wahgi collection, it is the one that contains the highest proportion of quartz grains, and shows least intermingling of source materials, so that it may be expected that the other greywacke specimens approach more closely to the composition of the Purari greywacke.

The difference in composition between the greywacke and the zeolitic tuff (Table 3, Analysis No. 2) is so evident as not to require comment.

Andesite Tuffs

Marine tuffs, containing foraminifera, predominate among the sandy specimens.

Coarse Tuff or Fine Agglomerate

Three specimens, Nos. 9026, 9070 and 9071, are coarsely fragmental rocks, with individual fragments up to 1 cm. across. No. 9071, the freshest specimen, is a greenish-grey rock, consisting essentially of crystals of plagioclase and pyroxene, together with numerous fragments of andesite, set in a matrix of minute fragments of pyroxene, felspar, andesite and clay. It contains, in addition, occasional flakes of biotite and a little chlorite, but there is no quartz and no glauconite.

The plagioclase grains are crystals or fragments of crystals up to 1 mm. across, and from their zoning and twinning, and extinction angles, appear to consist of cores of andesine with outer zones of oligoclase, or else of oligoclase throughout. They can be matched with some of the felspar phenocrysts of the andesite fragments. The felspar is fresh, but in places is partly replaced by calcite.

The pyroxene grains are as large as 2 mm. by 1·5 mm., though most are smaller. They are quite fresh, and some are idiomorphic crystals, though angular fragments predominate. Augite is the most common species, and includes a colourless variety and a greenish variety. Hypersthene is present as an occasional grain, pleochroic from pale green to brownish. Similar pyroxenes occur as phenocrysts in some of the andesite fragments, so that there can be no doubt as to the source of the free grains. The biotite occurs as small flakes, pleochroic from straw-yellow to green, and in places twisted or flexed.

The numerous andesite fragments range in size from 0·2 mm. to 10 mm. across. They are angular and roughly equidimensional, and though replaced in part by calcite and chlorite, have a uniformly fresh appearance, indicating that there was no differential weathering of the fragments prior to deposition. The fragments vary considerably in texture, but not greatly as regards mineral composition. The larger fragments consist of phenocrysts of oligoclase about 0·2 to 0·5 mm. long, together with pyroxene phenocrysts of similar size, and chlorite

pseudomorphs after (?)hornblende, in a fine-grained groundmass of oligoclase laths, small prisms and granules of pyroxene, and more or less devitrified brownish-green glass. Patches of calcite occur in some, partly replacing felspar phenocrysts, and some of the chlorite appears to be encrusting vesicles.

Other fragments contain corroded microphenocrysts of oligoclase, somewhat replaced by carbonate, in pilotaxitic or hyalopilitic groundmasses. Phenocrysts of fresh pyroxene are present in some of these fragments, in others only chlorite pseudomorphs occur. Other fragments consist of similar phenocrysts in a devitrified glassy base, and some fragments consist of groundmass only.

There are no fragments of sedimentary rocks.

Specimen No. 9070 is generally similar to No. 9071, but is severely weathered. It consists essentially of altered grains of plagioclase and pyroxene, and fragments of igneous rocks, in a fine matrix of similar material. The igneous rock fragments consist in part of fine-grained andesite, some with and some without phenocrysts of plagioclase and pyroxene, and in part of clots of altered, intergrown augite and enstatite crystals. The largest augite-enstatite fragment observed measured 5 mm. by 2 mm., and the individual pyroxene grains composing it were about 0·2 mm. across. In addition there are composite fragments 2 mm. by 2 mm. of coarse plagioclase crystals.

Zeolitic Tuffs

Specimen No. 9026 is a coarse fragmental rock, generally similar to No. 9071 in hand specimen—a greenish rock with limonite staining along joints, and containing rock fragments up to 10 mm. across, and white felspar crystals 2 to 3 mm. long, which show on a fractured surface.

Thin sections show that it is a coarse tuff, composed of numerous angular fragments, up to 5 mm. across, of fine-grained andesites, and prismatic crystals of plagioclase, some in glomeroporphyritic clusters, 2 to 3 mm. long, together with occasional grains of fresh pyroxene, chiefly augite, in an abundant cement consisting of a lime zeolite, probably laumontite, and some chlorite.

The andesite fragments show a variety of textures similar to the fragments in No. 9071. Some contain chloritized ferromagnesian phenocrysts, but the granules of pyroxene in the groundmass of such rocks tend to be fresh. The plagioclase crystals are zoned and twinned, and range in composition from labradorite at the core to marginal zones of oligoclase.

The cementing material is the most striking feature of the rock (Plate III, fig. 4). It is composed of more or less equigranular crystals of a zeolite, studded with swarms of ovoids or oolitic bodies of greenish chlorite, occasional ovoids of colourless zeolite, and very occasional ovoids of calcite.

The dominant zeolite forming the host to the various oolitic bodies is optically negative and biaxial, with 2V about 20° to 30°. It has a perfect cleavage in one direction, and a refractive index on cleavage fragments of 1·513. The birefringence is about 0·009. Occasional grains show traces of a second cleavage. These various properties indicate that the mineral is a lime zeolite, probably laumontite ($CaAl_2Si_4O_{12}.4H_2O$), or possibly scolescite or epistilbite. This finds confirmation from the chemical analysis of the zeolitic tuff, No. 9024 (Table 3, Analysis 2). The individual grains are 0·2 mm. across, and some are water clear, but the majority are cloudy from dust-like inclusions. Dispersed through this zeolite are occasional ovoids of other zeolites, one of which is biaxial and negative, closely resembling the main zeolite, and a second that is uniaxial and negative.

The prevailing ovoid bodies are composed of a greenish-yellow chlorite, and consist either at the core or throughout of spherulitic fibrous growths (Pl. III, fig. 4). Some show two or three sharply defined concentric zones, and most have a narrow brown marginal zone. An occasional ovoid has an outer zone of colourless zeolite, while some of the zeolitic ovoids have a rim of the chlorite. Some of the chlorite bodies are elongated or distorted by compaction between the grains or rock fragments, and some fill interstices, and are shaped accordingly. They range in size from 0·01 mm. to 0·10 mm. in major diameter, and occur in clusters of a hundred or more, in which all sizes in this range are represented. Generally in one field of view all of the adjacent ovoids have their longer axes parallel to one another (Pl. III, fig. 4); but the orientation varies from place to place in the section. Occasionally two and three ovoids can be seen to have coalesced, or to have been compressed against each other, with resulting distortion of their shape (Pl. III, fig. 5). The chlorite is pleochroic from pale green to apple green, and shows yellow polarization colours and negative elongation.

The zeolites and the chlorite bodies appear to have formed from the solution and redeposition as gels of the components of the felspars and ferromagnesian minerals of the tuff during diagenesis. The iron and magnesium could not be accommodated in the zeolites, and so formed separate bodies of chlorite.

The andesitic fragments are in general not replaced by the chlorite, but an occasional fragment has been severely chloritized, and one fragment was observed crowded with chlorite ovoids. Some of the plagioclase crystals have been invaded by narrow seams of chlorite along their cleavage planes, and some are partly replaced by calcite; but the pyroxene grains are quite unaffected by either chlorite or calcite. In places the groups of chlorite bodies are enclosed within areas of a green fibrous material, apparently a second chlorite substance, intensely pleochroic from emerald green to straw yellow, and suggestive of glaucophane.

In addition there are occasional grains about 0·15 mm. across of magnetite-ilmenite lattice intergrowths, in which the ilmenite lamellae of the lattice are altered to leucoxene, leaving the magnetite unaltered.

Specimen No. 9024 is a fine-grained variant of No. 9026, but lacks the chlorite ovoids. It consists of grains of plagioclase and fresh pyroxene, and numerous fragments of somewhat altered fine-grained andesite and chloritic material, together with very occasional fragments of quartzite, in an abundance of zeolitic cement, which appears identical with that of No. 9026, and is the dominant component of the rock, occurring as interlocking equigranular allotriomorphic crystals (Pl. III, fig. 6). In places the zeolite has formed elongated areas or narrow seams showing a tendency to radial fibrous growths from the walls. In addition there are occasional grains of bright yellow epidote, and areas of carbonate, or of carbonate replaced by zeolite, showing definite organic structures, relicts of some marine organism.

The felspar grains are sodic plagioclase, and are invaded by seams of chlorite and more or less replaced. The pyroxene is chiefly colourless augite with a large extinction angle, but some enstatite is also present. The andesite fragments are about 0·2 mm. across, and are rounded to sub-angular. They show varying stages of alteration from intense to only partial chloritization.

The chlorite, which is abundant, occurs as more or less discrete grains. It appears partly to be a product of the replacement of andesite fragments, and partly of biotite grains. Some of it may be altered glauconite.

Chemical Analysis

The unusual composition of these rocks is emphasized by a chemical analysis of Specimen No. 9024, shown in Table 3 (Analysis No. 2). The low silica, and the high lime, alumina and combined water contents, reflect the abundance of the zeolite cement, and the low soda content confirms that it is a lime zeolite.

The tuff is much more basic than the greywacke (Analysis No. 1), or even than the analysed Miocene greywacke of the Aure Series of Papua (Table 3, Analysis No. 4, 4a), which is largely derived from andesitic tuff, and contains practically no quartz (Edwards, 1950a). The tuff is notably richer in lime and combined water, and poorer in soda and silica than the Miocene greywacke, which approximates to average andesite in composition. However, the alumina and potash contents of the two rocks are similar. Since the Wahgi tuff originated from pyroxene andesites, it is evident that the zeolites in this tuff formed largely at the expense of the original felspar, and that soda and silica were lost in solution in the process.

The P_2O_5 content of the zeolitic tuff is the same as that of the greywacke (Analysis No. 1), despite the fact that apatite is practically absent from the heavy minerals of the tuffs, though it is prominent among the heavy minerals of the greywacke. This must indicate solution of the original apatite of the andesite fragments during the zeolitization of the tuff, and either (a) absorption of phosphorus in the zeolite, or (b) deposition of a secondary phosphate mineral not recognized as such in an examination of the thin sections.

Sandy Tuffs

With the appearance of quartz grains and glauconite or altered glauconite, these tuffs grade into sandy tuffs. Specimens Nos. 9051, 9053, 9056 and 9057 represent the initial stages of this transition from a zeolitic tuff, such as No. 9024, to the sandy tuff. All four are characterized by an abundance of grains of fresh pyroxene, with rather fewer grains of plagioclase, numerous fragments of andesite, a number of angular grains of quartz, and numerous grains of more or less altered glauconite, in a zeolitic cement. The pyroxene crystals are up to 0·3 mm. across, and are either fresh or have a rim of limonite in severely weathered rock. They are colourless to greenish. Both augite and enstatite are present, but augite is much the more abundant.

The andesite fragments are all fine-grained, and show the same range of texture and composition as in the tuffs proper. Some are severely chloritized, others practically unaltered. Some are more or less completely replaced by clots of yellow epidote. Sedimentary rock fragments are represented by only a very occasional fragment of quartzite, one of which was studded with growths of iron sulphide.

The quartz grains are uniformly distributed through the rocks, and are always angular. They are generally smaller than the other grains. Fresh glauconite, and grains showing all stages of alteration to a pale yellowish isotropic substance, are relatively numerous. Some are ovoid, others are more or less angular to subangular. These various grains are enclosed in a zeolitic cement, composed chiefly of laumontite.

These rocks are reported as unfossiliferous, but in the sections of both Nos. 9053 and 9056 there are occasional areas of calcite showing definite organic structure, suggestive of foraminifera.

Specimens Nos. 9014, 9018 and 9063 fall into this transitional group, but contain less zeolitic material, and more quartz. They consist essentially of closely

packed angular fragments of andesite, about 0·2 to 0·5 mm. across, together with occasional grains of plagioclase and pyroxene, and a number of angular grains of quartz, which are about 0·1 mm. long in No. 9063, and occasionally as large as 0·3 mm. long in Nos. 9014 and 9018. This quartz occurs in the main as noticeably smaller grains than the other grain components. One fragment in No. 9018 showed a rounded embayment filled with chlorite. Both Nos. 9018 and 9063 are reported not to contain organisms, but No. 9018 can be seen in thin section to contain fragments of echinoids, mollusca, and calcareous algae.

Specimen No. 9022 is a fine-grained sandy tuff, verging on mudstone as regards grain size, and could be so classed. It is traversed by a narrow veinlet lined with quartz and (?)pyroxene needles.

Specimens Nos. 9047 and 9048 represent a further stage in the progression towards greywacke. They contain only a very little pyroxene, and much more quartz and glauconite than the other sandy tuffs, together with a little orthoclase, and fragments of chert, phyllite and shale, in addition to andesite. Specimen No. 9093 is generally similar, but is stained red-brown by iron oxide.

Heavy Minerals

The heavy minerals were extracted from two samples of tuff proper, Nos. 9026 and 9071, and two sandy tuffs, Nos. 9053 and 9063. The two tuff samples yielded an abundance of pyroxene fragments, consisting of colourless augite, green augite, and an occasional grain of hypersthene, a little epidote, and a few grains of iron ore and biotite, but no other minerals.

Of the sandy tuffs, the near tuff No. 9053 yielded an abundance of similar pyroxenes. In addition there is a very occasional grain of glauconite, an occasional minute prism of apatite, and a very occasional grain of brown tourmaline.

The more sandy specimen, No. 9063, by contrast, gave a relatively small heavy product, but it contains, in addition to a moderate proportion of the pyroxenes, all of the heavy minerals of the greywackes, though mostly as small grains only. They range between 0·02 and 0·05 mm. diameter. Apatite is the most abundant, occurring largely as minute water clear prisms, but partly as well-rounded dusty grains. Zircon occurs as occasional double-ended prisms, but chiefly as squat pyramidal grains, more or less completely rounded. Topaz is present as rather larger waterworn grains, and tourmaline occurs as the characteristic golden-brown and smoky varieties, in general waterworn. Rounded grains of glauconite occur in some abundance, and there are occasional grains of pink and brown garnet. The pyroxene occurs as fresh angular fragments of colourless and green augite, and there is an abundance of rounded leucoxene grains with a few rounded iron ores.

It appears from the relative proportions of heavy detrital minerals present in these two sandy tuffs that there is a direct correlation between abundance of detrital minerals and abundance of angular quartz as seen in thin sections.

Mudstones

A number of the rocks in the collection are mudstones, some verging on fine sandstone, namely Nos. 9020, 9021, 9060, 9062 and 9065. Some are too fine-grained for their components to be distinguished under the microscope, but most of them contain tuffaceous matter, felspar, pyroxene granules and zeolites, with a little angular quartz, in a clay matrix. Presumably they consist of intermingled tuffaceous and detrital material. No. 9020 shows complex crenulations suggestive of slump structures. No. 9078 is a heavily carbonated mudstone of this type.

Specimen No. 9094 is a black shale or sandy shale, with an abundance of fine angular quartz, cloudy felspar, shreds of biotite and muscovite, clayey patches, leucoxene, and carbonaceous matter, together with disseminated patches of carbonate and occasional shell fragments, but nothing suggestive of tuff. Blebs of iron sulphide are associated with the seams of carbonaceous matter.

Limestones

Three specimens of limestone are included in the collection. No. 9017, from Stage 4 (Chimbu Tuffs), in the Eocene portion of the section, is a brownish-grey limestone containing foraminifera and calcareous algae, reported as *Fasciolites wichmanni* (abundant), *Lacazina wichmanni, Textularia sp.,* and *Halimeda*, in a list of unpublished fossil determinations supplied with the suite of specimens by the Bureau of Mineral Resources. In thin section it shows no mineral grains or tuff fragments. Dissolution with acetic acid left a small residue of brownish clay-like material, but no mineral grains. Qualitative analysis showed the limestone to consist essentially of calcium carbonate, with a very minor amount of magnesium carbonate. Deposition of the limestone must have occurred, therefore, outside the range of sandy sediment, and during a period of volcanic quiescence.

The other two specimens, Nos. 9077 and 9087, consist of shells and shell fragments, of *Buchia malayomaoria* and *Inoceramus*, in a matrix of clay, carbonate material being the dominant component. Specimen No. 9077 might be described alternately as a red calcareous mudstone, the clay matrix being stained bright red with iron oxides. Some of the shell fragments enclose minute patches of zeolites, and some are fringed with a bright green pleochroic carbonate mineral. This rock contains no trace of quartz grains, but No. 9087 contains occasional grains of quartz about 0·01 mm. across.

In addition to these true limestones, there are two specimens of calcareous shale, Nos. 9078 and 9079, in which the carbonate occurs as a cement, replacing any original matrix in the rock, and to a large extent replacing the grains of the rock. It is probable that in these rocks the carbonate was introduced during diagenesis or lithification, and the original sediments were not limestones. No. 9078 contains fragments of andesite and ill-defined felspar, and very little quartz, so that it was tuffaceous in origin. No. 9079 contains abundant angular quartz and some muscovite, so was mainly sediment, probably similar to No. 9094.

Cherts

Two specimens, Nos. 9073 and 9074, consist of chert. No. 9073 is reported to contain radiolaria (*Spumellaria*), in part replaced by glauconite. It consists of a hard greenish chert, composed of sericite, chlorite, and amorphous silica, through which are distributed very occasional angular grains of quartz, small areas of chlorite, and patches of calcite. Distributed through the rock are stumpy, lens-like bodies, about 0·05 mm. long, of chlorite, or chlorite with a core of quartz. These may represent original radiolaria; but they bear some resemblance to the chlorite bodies in the zeolitic tuff (No. 9026). The chlorite is distinguished from glauconite by its apple green colour, and ultra-blue polarization colours.

Specimen No. 9074 is a similar rock, shattered by more or less rectangularly disposed fractures, which have been healed with carbonate, or fine-grained quartz. The rock contains less chlorite than No. 9073, but contains numerous radiolaria which appear as circular to ovoid areas of silica, calcite or chlorite. Some of the

calcitic bodies show a reticulate structure, and many of them contain inclusions of minute opaque bodies.

Conditions of Sedimentation

The Wahgi sediments consist in part of tuff, and in part of detrital sediments, derived from a neighbouring landmass.

The tuffaceous material appears to have been deposited directly in the sea, since there is nothing in the way of differential weathering of the tuff fragments in a given thin section to indicate previous deposition on a land surface. The more or less crystalline character of the groundmass of many of the tuff fragments points to sub-aerial rather than submarine eruption. The fragments are invariably andesitic.

The detrital material appears to have been derived chiefly from older sediments, in view of the predominance of phyllite, shale and quartzite among the rock fragments. The abundant quartz grains are generally too fine-grained to be derived directly from granite, in view of the fact that their angular form indicates that they have not been transported any great distance. The well rounded form of many of the detrital heavy mineral grains in the greywackes indicates that these grains were derived from pre-existing sediments, and had undergone at least one previous cycle of erosion. It may be concluded, therefore, that the granite which the Wahgi sediments overlie, and which outcrops in the Bismark and Kubor Ranges, served as a surface of deposition, rather than as a source, for the sedimentary material.

The volcanic activity was intermittent, so that periods of sudden deposition of large volumes of tuffaceous material alternated with periods of volcanic quiescence, when the greywackes were formed. With less vigorous eruption the sandy tuffs resulted. The coarsely fragmental nature of some of the tuffs points to nearness to the volcanic vents; and the angular shape of the tuff fragments as compared with the rounded phyllite, shale, and quartzite fragments, suggests aerial transport for much of the tuff, and water transport for the sedimentary fragments.

The changes undergone by the rocks during diagenesis and lithification appear to be dependent on their original composition to a considerable degree. The greywackes tended to undergo more or less intensive carbonation, with development of calcite cement. The tuffs, with their abundant fine matrix of felspar and ferromagnesians, underwent some degree of hydration and solution that gave rise to an abundant cement of zeolites and some chlorite. These solidified at first as gels, subject to deformation.

The badly sorted nature of the sediments, their great thickness, and their fine-grained character, points to rapid deposition in a subsiding basin of deposition, which conforms with their situation in the Papuan geosyncline.

There is a general resemblance between the greywackes of the Wahgi section and the Purari greywackes (Edwards, 1950), emphasized by the presence of glauconite and apatite in both. The Wahgi rocks, however, tend to contain more quartz than the Purari rocks, and in addition lack the hornblende and fragments of hornblende andesite found in the Purari. The heavy mineral suites differ, also. Topaz is absent from the Purari sediments. Small pyramidal zircons characterize the Wahgi rocks, whereas prismatic zircons are more abundant in the Purari greywackes. Both series contain abundant apatite, but the abundant "dusky" apatites of the Purari suite are only weakly represented in the Wahgi rocks. Both contain abundant tourmaline, but the golden-brown variety characteristic of the Wahgi is lacking in the Purari.

The general indication, therefore, is that the two series were deposited under generally similar conditions, but derived from different terranes. Moreover, the vulcanicity was less pronounced in the Purari region.

Tectonic Environment of Sedimentation

The great thickness of the Mesozoic strata in the Wahgi Valley, amounting to nearly 16,000 feet for the sequence from about the base of the Upper Jurassic to the Cenomanian, corresponds to an estimated rate of deposition of about 0·1 mm. per year. This is a medium rate of deposition according to Stille (1944), who has recently analysed rates of deposition in various tectonic environments, and finds similar rates in the Tertiary idiogeosynclines of Indonesia, the Variscan foredeeps of Western Europe, and the intermontane basins in the Cordillera of Western America. He considers these depositional troughs as 'subsequent' or 'post-orogenic' undations.

The Wahgi Mesozoic sequence forms part of the 'folded sedimentary zone' of Central New Guinea (Glaessner, 1950), and similar sediments seem to underlie most of this zone. The Jurassic Maril Shales rest on the Kubor granite (Noakes, 1939), which is older than the Permian limestones overlying its western end (Glaessner, Llewellyn and Stanley, 1950). The uppermost members of the Wahgi sequence are locally overthrust from the north by similar granites, which form part of the Bismark Mountains. Remnants of Mesozoic strata, including equivalents of the Kondaku Tuffs, are faulted into the plutonic and metamorphic rocks of the 'crystalline zone', which lies north of the predominantly sedimentary zone. or are preserved as cappings on it. Towards the east the Wahgi sediments disappear under Upper Tertiary rocks which grade into the filling of the Aure Trough. The unaltered Mesozoic rocks are not seen again. Their place is taken by the Kaindi Metamorphics of the Owen Stanley Ranges, in which Cretaceous fossils occur locally.

The great thickness and areal extent of the Mesozoic rocks makes their geosynclinal character obvious. The rapid deposition of lithologically similar strata must have occurred in a subsiding trough. The rocks maintain uniform facies until Middle Eocene time, when shallow water limestones and conglomerates indicate a change in environment. The almost complete absence of initial vulcanism, and of synorogenic plutonism, which is usually accompanied by regional metamorphism, indicates that the Wahgi sediments were deposited in a miogeosyncline. This is confirmed by their position in relation to the cratonic stable area of Australia, which at the time of their deposition included the folded Palaeozoic rocks of the eastern geosyncline and the granitic batholiths of this zone extending across Torres Strait into southern New Guinea. Extensive basins in the Palaeozoic folded zone were being filled with lacustrine Triassic and Jurassic deposits, and with intermittently marine Cretaceous deposits, while other parts of this stable area provided a source of detrital material. This could account for the granitic and sedimentary material of the Purari greywackes (Edwards, 1950) and for the 'greensands' in the Cretaceous of Western Papua (Kerabi Valley, and other areas), but the detrital material of the greywackes in the Wahgi-Chimbu section, which is about 50 miles further north from the southern margin of the geosyncline, is of a different nature, and appears to be derived from a less granitic terrain. One locality cannot yield sufficient evidence of the direction of transport of this material, but as a working hypothesis it is suggested that its source lay to the north, where we also must look for the source of the abundant volcanic material. The Purari Formation contains less andesitic detritus at its type locality than its tuffaceous

equivalents in the Wahgi Valley. The source of the material can be pictured not as a 'borderland', but as a zone of island arcs, which came into existence in a Mesozoic eugeosyncline. The Tertiary strata in northern New Guinea and the Bismarck Archipelago rest generally on a plutonic or metamorphic basement, indicating strong pre-Tertiary plutonism, which has wiped out all traces of unaltered Mesozoic sediments. This zone is considered to be the site of a late Mesozoic (or early Tertiary) eugeosyncline. The intermittent character of the vulcanism, which was weak or absent in the Jurassic, strong in the Lower Cretaceous, weak in the Cenomanian, and strong again in the Lower Chimbu Tuffs, is in keeping with the development of a geosynclinal zone in which volcanic island arcs appear, move, and disappear intermittently. The outward sequence from craton (with epi-continental deposition) to miogeosyncline (a marginal, rapidly sinking shelf) and thence to peripheral eugeosynclinal 'volcanic troughs and linear islands' not only parallels the conditions in the Appalachian geosyncline in Palaeozoic time (Kay, 1944), but is comparable with the conditions on the margin of Sundaland during the Tertiary.

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Explanation of Plate III

Fig. 1.—Greywacke No. 9403, showing an angular quartz grain, with quartz overgrowth, outlined by inclusions, together with fragments of andesite and shale. × 50.

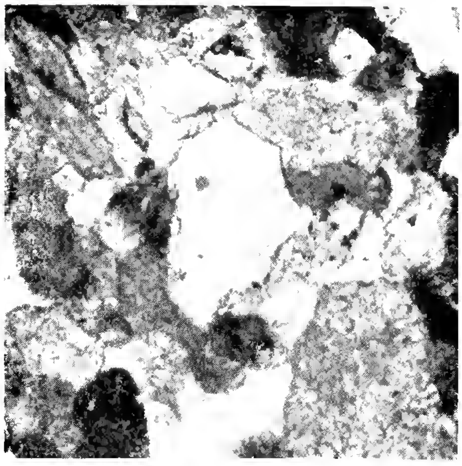
Fig. 2.—A large rounded fragment of phyllite, characteristically elongated parallel to its bedding or cleavage, in greywacke No. 9403. × 50.

Fig. 3.—Greywacke No. 9608 (analysed specimen), showing characteristic texture, with ill-sorted angular grains of quartz and felspar as the dominant grains. × 25.

Fig. 4.—Chlorite ovoids showing parallel elongation and compaction effects, in a matrix of lime zeolite (?laumontite), in coarse zeolitic tuff No. 9206. × 25.

Fig. 5.—Three chlorite ovoids, enclosed in laumontite, and compressed into one another, presumably during compaction, in zeolitic tuff No. 9206. × 50.

Fig. 6.—Typical field of view of zeolitic tuff No. 9024 (analysed specimen), showing the abundance of coarse crystalline lime zeolite (?laumontite), colourless to light grey, with cleavage, together with small grains of fresh pyroxene (high relief) and fragments of altered andesite (dark). × 25.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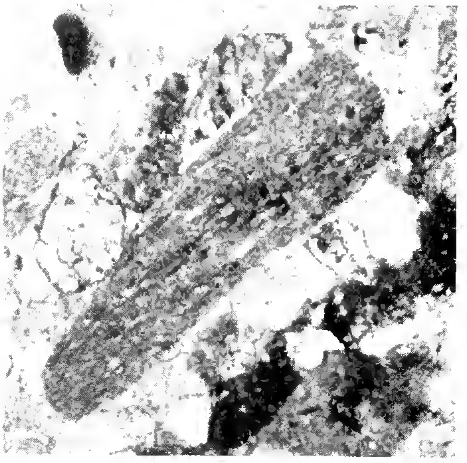
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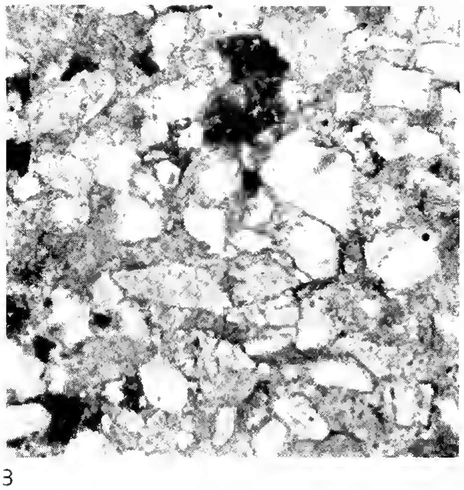
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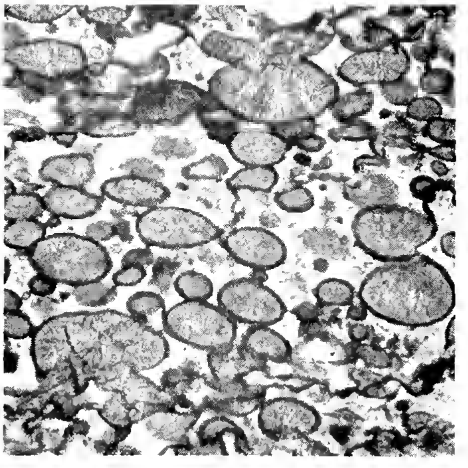
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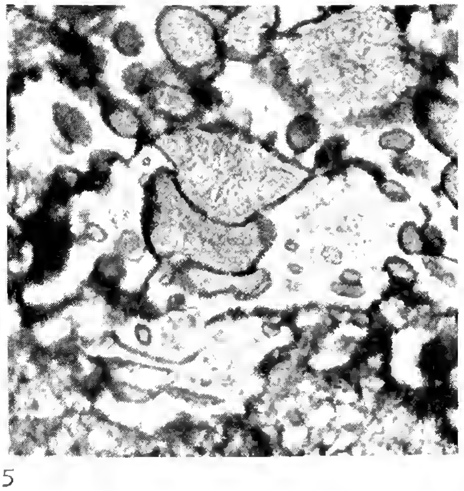
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Coats, R. P., Geology Department, The University, Carlton, N.3 1951
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Cochrane, G. W., M.Sc., Mines Department, Adelaide, South Australia 1945
Collins, A. C., 9 McDonald Avenue, Newtown, Geelong 1928
Condon, M. A., M.Sc., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot Road, Hawthorn, E.2 1919
Cookson, Miss I. C., D.Sc., 154 Power Street, Hawthorn, E.2 1919
Coulson, A., M.Sc., 5 Victoria Street, Preston, N.18 1929
Court, A. B., Childs Road, Kalorama 1949
Cowen, Miss Margot E. H., B.Agr.Sc., Department of Agriculture, Palmerston North, New Zealand 1936
Crespin, Miss I., B.A., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1919
Crohn, P. W., M.Sc., Mines Department, Melbourne, C.2 1946
Croll, I. C. H., M.Sc., 53 The Boulevard, Hawthorn, E.2 1934
Croll, R. D., B.Agr.Sc., 18 Russell Street, Camberwell, E.6 1940
Currey, D. T., 164 Ormond Road, Elwood, S.3 1948
Dadswell, Mrs. Inez W., M.Sc., 72 Florizel Street, Burwood, E.13 1939
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22 1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9 1946
Eadie, J. M., B.Sc., State Rivers and Water Supply Commission, 31 Flinders Lane, Melbourne, C.1 1949
Edwards, G. R., B.Sc., High School, Portland 1937
Elford, F. G., B.Sc., B.Ed., 76 New Street, Brighton, S.5 1929
Elford, H. S., B.E., c/o Tait Publishing Company, 349 Collins Street, Melbourne, C.1 1934
Esplan, W. A., 19 Retreat Road, Hampton, S.7 1951
Essame, J. C. L., B.A. (Camb.), Mines Department, Melbourne, C.2 1951
Fawcett, Miss Stella G. M., M.Sc., Botany Department, The University, Carlton, N.3 1937
Finlay, Miss C. J., B.Sc., Geology Department, University of Melbourne, Carlton, N.3. 1950
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7 1949
Forster, H. C., B.Agr.Sc., Ph.D., 6 Glendene Avenue, Kew, E.4 1938
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16 1933
Gaskin, A. J., M.Sc., Geology Department, The University, Carlton, N.3 1941
Gladwell, R. A., 79 Cochrane Street, Elsternwick, S.4 1938
Glenister, B. F., B.Sc., Geology Department, University of Melbourne, Carlton, N.3 .. 1950
Gordon, Alan, B.Sc., c/o C.S.I.R.O., Yarra Bank Road, South Melbourne, S.C.4 .. 1938
Gunson, Miss Mary, M.Sc., Zoology Department, The University, Carlton, N.3 1944
Hardy, A. D., 24 Studley Avenue, Kew, E.4 1913
Hauser, H. B., M.Sc., Geology Department, The University, Carlton, N.3 1919
Haycraft, J. A., 27 Yeovil Road, Burwood, E.13 1951
Head, W. C. E., 50 Macpherson Street, Nhill 1931
Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia 1935
Hill, R. D., D.Sc., Physics Department, University of Illinois, Urbana, Ill., U.S.A. .. 1946
Hitchcock, W. B., National Museum, Russell Street, Melbourne, C.1 1949
Hogan, T. W., M.Agr.Sc., 22 Cornell Street, Burwood, E.13 1947
Holland, R. A., 526 Toorak Road, Toorak, S.E.2 1931
Holmes, A. J., B.Sc., 606 Glenhuntly Road, Caulfield, S.E.8 1949
Holmes, W. M., M.A., B.Sc., 1 Balmoral Avenue, Kew, E.4 1913
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21 1934
Hutchinson, R. C., B.Sc., Department of Agriculture, Rabaul, New Guinea 1939
Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Agr.Sc., Botanical Gardens, South Yarra, S.E.1 1927
Jones, D. Spencer, B.Sc., 31 Winmalee Road, Balwyn, E.8 1952
Jones, L. H. P., M.Sc., Ph.D., Chemistry Department, The University, Carlton, N.3 .. 1948
Kenley, P. R., B.Sc., 4 Anthony Street, Ormond, S.E.14 1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4 1942
Langtry, J. O., 15 Boston Road, Balwyn, E.8 1950
Law, P. G., M.Sc., 10a Copelen Street, South Yarra, S.E.1 1946
Lindner, A. W., B.Sc., Bureau of Mineral Resources, Canberra, A.C.T. 1949

Lynch, D. D., 179 Park Street, Parkville, N.2 1950
McLennan, Assoc. Prof. Ethel, D.Sc., The University, Carlton, N.3 1915
McNally, J., B.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.3. 1950
MacPherson, Miss J. Hope, B.Sc., National Museum, Russell Street, Melbourne, C.1 .. 1940
Manning, N., 733 Punt Road, South Yarra, S.E.1 1940
Marsden, M. A. H., 68 Champion Street, Middle Brighton, S.5 1952
Medwell, Miss L. M., B.Sc., Geology Department, The University, Carlton, N.3 .. 1952
Melhuish, T. D'A., M.Sc., c/o Elliots & Australian Drug Pty. Ltd., Terry Street, Rozelle, N.S.W. 1919
Mitchell, A. W. L., B.Sc., 71 Radnor Street, Camberwell, E.6 1946
Mitchell, Miss J., National Museum, Russell Street, Melbourne, C.1 1949
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9 1945
Morris, P. F., National Herbarium, South Yarra, S.E.1 1921
Moy, A. F., B.A., Melbourne Boys' High School, Forrest Hill, South Yarra, S.E.1 .. 1943
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, The University, Carlton, N.3 .. 1940
Neilson, J. L., 1 Fordham Avenue, Camberwell, E.6 1952
Nye, E. E., College of Pharmacy, 360 Swanston Street, Melbourne, C.1 1932
Oke, C., 34 Bourke Street, Melbourne, C.1 1922
Osborne, N., c/o Australasian Petroleum Company, Port Moresby, Papua 1930
Pike, Miss K. M., B.Sc., Botany Department, The University, Carlton, N.3 1948
Pinches, Mrs. M., 5A Second Avenue, North Williamstown 1943
Pretty, R. B., M.Sc., 62 Glen Iris Road, Glen Iris, S.E.6 1922
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5 1948
Rowney, George, B.Sc., 20 Belson Street, East Malvern, S.E.5 1952
Samson, H. R., M.Sc., Industrial Chemistry Division, C.S.I.R.O., Box 4331, Melbourne, C.1 1945
Schleiger, N. W., B.Sc., "Elmhurst," Napier Street, White Hills, Bendigo 1949
Seeger, R. C., 56 Jenkins Street, Northcote, N.16 1946
Shaw, N. J., 192 Victoria Street, West Brunswick, N.12 1950
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W. 1918
Shipp, A., "Gangort," Canterbury Road, Heathmont 1946
Singleton, O. P., M.Sc., Geology Dept., University of Western Australia, Nedlands, W.A. 1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6 1932
Stevens, N. C., B.Sc. (Sydney), 12 Salisbury Street, Hurstville, N.S.W. 1951
Thomas, G. A., B.Sc., 39 Duffy Street, Ainslie, Canberra, A.C.T. 1944
Thomas, L. A., B.Sc., C.S.I.R.O., Stanthorpe, Queensland 1930
Threader, V. M., B.Sc., 63 Glenferrie Road, Kew, E.4 1950
Trüdinger, W., 27 Gerald Street, Murrumbeena, S.E.9 1918
Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R.O., Cronulla, N.S.W. 1936
Tugby, D. J., National Museum, Russell Street, Melbourne, C.1 1949
Tylee, A. N., 31 Wingan Avenue, Camberwell, E.6 1951
Vasey, G. H., B.C.E., The University, Carlton, N.3 1936
White, D. A., B.Sc. (W.A.), Geology Department, The University, Carlton, N.3 .. 1951
White, Miss Lillian, B.Sc., Royal Merchant Navy College, Bear Wood, Wokingham, Berks., England 1947
Whitehead, Mrs. Sylvia, M.Sc., 48 Invermay Grove, Rosanna 1942
Woodburn, Mrs. Fenton, 21 Bayview Crescent, Black Rock, S.9 1930
Wymond, A. P., M.Sc., Division of Forest Products, C.S.I.R.O., P.O. Box 18, South Melbourne, S.C.4 1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1951

The President and Council present to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1951.

The following meetings of the Society were held:

March 8th.—Annual Meeting. The following office-bearers were elected: *President,* Professor J. S. Turner; *Vice-Presidents,* Dr. F. L. Stillwell, Professor L. H. Martin; *Honorary Treasurer,* Mr. R. T. M. Pescott; *Honorary Librarian,* Mr. F. A. Cudmore; *Honorary Secretary,* Dr. C. M. Tattam; *Members of Council,* Professor E. S. Hills, Mr. E. R. Pitt, Professor O. W. Tiegs.

The following *Members of Council* continued in office: Mr. V. G. Anderson, Associate Professor G. W. Leeper, Dr. J. S. Rogers, Dr. D. E. Thomas, Professor G. L. Wood, and all past Presidents.

The Annual Report and Financial Statement for 1950 were read and adopted.
At the close of the Annual Meeting an Ordinary Meeting was held.—Exhibition of instructional films on heredity and meteorology.

April 12th.—Lecture: "The Hydrology of an Australian Forest," by Mr. J. D. Brookes.

May 10th.—Lecture: "Soil Mineralogy Investigations at the Macaulay Institute, Aberdeen, Scotland," by Dr. G. F. Walker.

June 14th.—Presentation of Clarke Memorial Medal to Dr. F. L. Stillwell; Illustrated Lecture: "Archipelago of the Recherche, Western Australia," by Mr. J. Béchervaise, with comments on the botany of the Archipelago by Mr. J. H. Willis.

July 12th.—Papers: "Notes on the Spines of a Tertiary Echinoid from Victoria," by Edmund D. Gill; "Victorian Musci, Part 1: Introduction and Andreaeaceae," by H. T. Clifford; "Distribution of the Species of Penicillium in some Victorian Soils," by Ethel McLennan.

August 9th.—Lecture: "The Coming Impact of Atomic Physics on Engineering," by Professor C. E. Moorhouse.

September 13th.—Lecture: "The Study of Respiratory Pigments," by Professor W. A. Rawlinson.

October 11th.—Papers: "The Wedderburn Meteoritic Iron," by A. B. Edwards; "The Geology of the Coastline of Waratah Bay between Walkerville and Cape Liptrap," by A. W. Lindner.

November 8th.—Lecture: "The Origin of the Solar System," by Professor E. J. Hartung.

December 13th.—Paper: "Mesozoic and Tertiary Sediments from the Wahgi Valley, New Guinea," by A. B. Edwards and M. F. Glaessner; Lecture: "The Outlook for Science in Malaya," by Professor J. W. H. Lugg.

During the year seven members, one country member and ten associate members were elected. One member and three associate members resigned. Two members and four associate members were removed from the list for non-payment of subscriptions. The total membership of the Society on December 31st, 1951, was 252.

The Council deeply regrets the death of WILFRED EADE AGAR, C.B.E., M.A. (Cantab.), D.SC. (Glasgow and Melbourne), F.R.S. Professor Agar was born at Wimbledon, England, in 1882, and educated at Sedbergh School, Yorkshire, and King's College, Cambridge, where he read Zoology. His first appointment was as demonstrator at Glasgow University, where he began researches in Cytology and Genetics, subjects upon which he was to become an international authority. He engaged upon an expedition to the Gran Chaco, Paraguay, to collect the lung-fish Lepidosiren which he was using as material for his studies in Cytology. During the 1914-18 war he served as a captain in the Highland Light Infantry. He returned to Glasgow after the war, and in 1920 was appointed to the Chair of Zoology at the University of Melbourne. In this same year he was elected a Fellow of the Royal Society of London. For some years he pursued his research in Cytology and Genetics but in later life devoted himself to the philosophy of science and the broader concepts of biology, expressed in his book *A Contribution to the Theory of the Living Organism*. He was called on to serve on many committees of the University and was President of the Professorial Board when that most important move in administration, the creation of the Vice-Chancellorship, was being put into effect. At all times he maintained the highest standards of teaching and scholarship. He retired from the Chair in 1948 with the title of Emeritus Professor and in that year received the award of C.B.E. in recognition of his services to science and the University. He became a member of the Society soon after his arrival in 1920 and served on the Council from 1922 to 1942. He was President for the years 1927-1928. He was held in high esteem by his colleagues and students for his tolerant outlook, balanced judgment and kindly personal qualities. He died on July 14th.

The attendances at Council meetings were as follows: Mr. Anderson, 10; Mr. Baragwanath, 8; Mr. Casey, 10; Mr. Cudmore, 10; Captain Davis, 9; Professor Hills, 8; Associate Professor Leeper, 6; Professor Martin, 1; Mr. Crosbie Morrison, 7; Professor Osborne, 1; Mr. Pescott, 9; Mr. Pitt, 7; Dr. Rogers, 4; Professor Skeats, 4; Dr. Stillwell, 10; Dr. Summers, 2; Dr. Tattam, 11; Dr. Thomas, 9; Professor Tiegs, 3; Professor Turner, 9; Professor Wadham, 3; Professor Wood, 4.

During the year 2,105 volumes and parts were added to the Library.

The Society received a proposal from the Australian Branch of the Royal College of Obstetricians and Gynaecologists that the Society grant the College permission to establish its headquarters in the Society's buildings. The necessary extensions, together with complete renovation of the present building, would be carried out at the expense of the College, at a cost of not less than £20,000. The Council agreed in principle to the proposal and negotiations for a formal agreement were proceeding at the close of the year. The advantages to the Society arising from the scheme will be a much needed increase in library accommodation, and general repair and renovation of the building.

HONORARY TREASURER'S REPORT

The financial position of the Society still gives cause for concern. Although the credit balance in the current account at December 31st, 1951, was £331.15.2, compared with £359.7.7 at the corresponding date of 1950, the financial position would not have been as satisfactory had it not been for an increase in the Government grant from £200 to £350. The Society expresses its appreciation of this action of the State Government to enable it to carry on its activities in these inflationary times.

On the expenditure side, the publication of the *Proceedings* absorbed the greater portion of the revenue. Publication costs are still rising rapidly, and unless some additional source of revenue can be found, it may be necessary to curtail this very desirable activity of the Society. This would be a retrograde step, as the *Proceedings* is not only the medium for the publication of valuable scientific papers, but is also the means whereby exchanges of scientific periodicals are obtained from overseas institutions.

General costs of administration of the Society's affairs have risen but little over a long period of years, and no drastic economies are possible there. On the receipts side, there are limits to the help that can be expected from the Government, which also has its financial problems. The other source of revenue is members' subscriptions, and this can be increased only in two ways, viz., an increase in full membership, or a substantial increase in membership dues.

Any great increase in membership can only be accomplished by spirited recruiting on the part of all members, and it is hoped that substantial increases in membership will occur in 1952.

The matter of the increase in membership dues is one that is receiving the consideration of your Council at the moment.

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1951

RECEIPTS

Balance in Bank at 1.1.1951		£359 7 7
Subscriptions—		
Members	£173 5 0	
Associate Members	80 16 0	
Country Members	24 3 0	
Arrears paid up	50 8 0	
		328 12 0
Rents—		
Commonwealth Government	£204 0 0	
Field Naturalists Club	16 0 0	
Microscopical Society	12 0 0	
		232 0 0
Sale of Publications		153 3 10
Interest on Bonds		14 5 0
Grants and Donations—		
Government of Victoria	£350 0 0	
University of Melbourne	251 11 1	
Sundry Donations	1 11 3	
		603 2 4
Sundries		11 12 4
		£1702 3 1

EXPENDITURE

Salaries—		
Assistant Secretary	£24 0 0	
Assistant Librarian	12 0 0	
Assistant Editor	30 0 0	
Hallkeeper	12 0 0	
Gardener	32 10 0	
		£110 10 0
Printing—		
Proceedings	£944 2 6	
General	135 18 5	
		1080 0 11
Light, Water and Gas		18 12 4
Telephone		18 11 1
Rates and Taxes		16 13 4
Subscriptions		8 0 4
Insurance		6 15 0
Petty Cash		7 5 0
Postage		74 17 5
Repairs and Replacements		11 2 9
Meetings		12 9 9
Fire Brigade		1 10 0
Sundries		4 0 0
Balance in Bank at 31.12.1951		331 15 2
		£1702 3 1

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
8th February, 1952.

T. M. CHERRY } *Hon.*
G. L. WOOD } *Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1.1.1951	£70 3 9	Balance at 31.12.1951	£71 11 9
Interest to 31.5.1951	1 8 0		
	£71 11 9		£71 11 9

LIFE MEMBERSHIP FUND

Balance at 1.1.1951	£175 6 7	Balance at 31.12.1951	£178 16 7
Interest to 31.5.1951	3 10 0		
	£178 16 7		£178 16 7

HOWITT MEMORIAL FUND

Balance at 1.1.1951	£127 10 5	Balance to 31.12.1951	£131 19 5
Interest on Bond	1 18 9		
Savings Bank Interest to 31.5.1951	2 10 3		
	£131 19 5		£131 19 5

T. S. HALL MEMORIAL FUND

Balance at 1.1.1951	£80 5 0	Balance at 31.12.1951	£81 17 0
Interest to 31.5.1951	1 12 0		
	£81 17 0		£81 17 0

BOOK-BINDING FUND

Balance at 1.1.1951	£114 16 2	Balance at 31.12.1951	£117 1 9
Interest to 31.5.1951	2 5 7		
	£117 1 9		£117 1 9

Accounts and Pass-books relating to each of the above Funds have been severally examined and found correct, and the Bank Certificates of Possession of Bonds amounting to five hundred pounds (£500), Savings Certificates to the face value of two hundred and fifty pounds (£250), and Fixed Deposit of two hundred pounds (£200) has also been inspected.

R. T. M. PESCOTT, *Hon. Treasurer.*

8th February, 1952.

T. M. CHERRY
G. L. WOOD } *Hon. Auditors.*

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